

DOCTOR OF PHILOSOPHY

Differentiation by Design

How New Product Design Creates Value and Competitive Advantage in Small Manufacturing Entities (SMEs)

Brown, Daniel

Award date:
2017

Awarding institution:
Coventry University

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of this thesis for personal non-commercial research or study
- This thesis cannot be reproduced or quoted extensively from without first obtaining permission from the copyright holder(s)
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Differentiation by Design

How New Product Design Creates Value and Competitive Advantage in Small Manufacturing Entities (SMEs)

Daniel Patrick Brown

March 2017

**A thesis submitted in partial fulfilment of the University's
requirements for the Degree of Doctor of Philosophy PhD**



Please add a copy of this section within the first few pages of your thesis, after your title page. Refer to 'Thesis Information Guidance' for more information.

Section 3 Submission Declaration

	Yes	No
Have materials contained in your thesis/submission been used for any other submission for an academic award?	<input type="checkbox"/>	X
If you have answered Yes to above please state award and awarding body and list the material:		
I am aware of no health reasons that will prevent me from undertaking and completing assessment and will undertake to notifying my Director of Studies and PGRSU - Registry as soon as any change in these circumstances occurs.	X	<input type="checkbox"/>
Ethical Declaration: I declare that my research has full University Ethical approval and evidence of this has been included within my thesis/submission. Please also insert ethics reference number below Project Reference: P 26277	X	<input type="checkbox"/>



The following **ethics** request has been approved by Martin Woolley. All the relevant documentation will be available for you to download within the next 24 hours. Please log back into **Ethics** and select the request from your listing. Select the Downloads tab to retrieve the documentation.

Please proceed with good **ethics**.

Ref:	P26277
Project Title:	Differentiation by Design Research
Applicant:	Daniel Brown
Supervisor:	Martin Woolley
Module Code:	
Module Leader:	

Go to ethics.coventry.ac.uk to view this request in more detail.

THIS MESSAGE HAS BEEN GENERATED AUTOMATICALLY - PLEASE DON'T REPLY TO THIS MESSAGE

Original citation:

Brown, D.P. (2017) How New Product Design Creates Value and Competitive Advantage in Small Manufacturing Entities (SMEs). Ph.D. Thesis. Coventry University: Coventry

Copyright © and Moral Rights are retained by the author(s) and/or other copyright owners. A copy can be downloaded for personal non-commercial research or study, without prior permission or charge. This item cannot be reproduced or quoted extensively from without first obtaining permission in writing from the copyright holder(s). The content must not be changed in any way or sold commercially in any format or medium without the formal permission of the copyright holders.

Dedication

I would like to dedicate this PhD effort to my parents Daniel and Myrtle (Mitch) Brown, without whose love and support in my life none of this work would have been possible. Both were immigrants' children of the depression, who had to struggle and fight simply to provide the necessities in life. They selflessly sacrificed every day for our family, and although we never had much from a material wealth perspective, we had the abundance of love and encouragement that we could achieve greater things in this life. Their beliefs, values, and examples have always guided me, and although they passed years ago, I feel that they are with me at all times. It has been their hopes and dreams for their oldest child, nurtured in me over fifty years ago, that motivated me to start this thesis at the age of fifty-five, and now complete it at the age of sixty. I am fortunate to have had this opportunity in life, provided by their sacrifices and love.

Acknowledgements

There are far too many individuals to properly acknowledge on one page, but I must recognize the following people for their support, guidance and efforts on my behalf through this journey. First, I must thank Martin Woolley. Martin is my Director of Studies, and I could not have been more fortunate. His intellect, experience and dedication to my work was invaluable in this process. When we met our discussions were rich and engaging; his insights helped me maintain focus, keeping me on course. Our frequent meetings and time together were the best part of this doctoral research.

I must also acknowledge my supervisors, David Durling, Louise Moody, and Deanna McDonough, who provided further guidance and direction along the way. Also, my colleagues at Northwestern who patiently listened as I continuously worked through my ideas and concepts, in particular David Gatchell and Lisa Del Torto who were always available to discuss the next reframing of thought I was debating. In addition, I must thank my students who have endured the evolution of my philosophy of design and how design is at the core of human knowledge, as they provided a live audience for me to refine my thesis. In addition, I had help in taking my crude graphic mockups and getting them into a publishable format for the thesis from Ghikhan Blossfeld-Lau and Hazel Yan. Finally yet most importantly, I want to recognize my friends and family for their support and encouragement along the way. This has been an incredible life experience, and I look forward to what the future holds for me.

ABSTRACT

In the practice of new product value creation there is a creative quest that product design and development practitioners must address when existing knowledge of practice proves inadequate but the development objective remains. Design practitioners often achieve new competitive advantages as the outcome of these creative quests, and yet truly innovative and competitive products are rare, as their efforts often fall short of the original design aims.

In this study, the design process of the author, a product design practitioner with over thirty years of experience, has been investigated through the examination of three case histories of successful new product development arising from his design practice. The cases were assembled by the practitioner, who is also an academic researcher, seeking an explanatory research analogue of his tacit design process.

The methodology draws on the reflective practice philosophy of Donald Schön, in conjunction with grounded theory and case studies employing mixed methods, to explain how design can create new value and competitive advantage in the marketplace. The chosen cases share common successful marketplace outcomes resulting from their design and development approaches. Although qualitative in nature, this autobiographic study builds on the insights available to the researcher, and the unique access to rich quantitative evidence of the design narrative and marketing histories gained from an insider's view of industry practice. Competitive advantage and its role in innovation in the real-world laboratory of the marketplace provide the context for researching the process of this design-focused strategy.

This thesis explains the practice-design relationship in strategic new product design and development by distinguishing between existing practice and the new knowledge rivalry created through design practice, bringing focus to the new design's ability to displace the existing solution. Whilst the primary focus of the study is on design value creation for competitive advantage in new product marketplaces, a new knowledge creation framework has emerged from this research with the potential for application by other practitioners. This strategically focused, differentiation by design based competency action model (CAM) provides a systematic explanatory framework for practitioners seeking advantaged new knowledge creation for product design praxis, as well as an actionable framework for further academic research.

“The trouble with the future is that it’s so much less knowable than the past. Because it lies on the other side of the singularity that is the present, all we can count on is that certain continuities from the past will extend into it, and that they will there encounter uncertain contingencies. Some continuity will be sufficiently robust that contingencies will not deflect them: time will continue to pass; gravity will keep us from flying off into space; people will still be born, grow old, and die. When it comes to actions people themselves choose to take, though - when consciousness itself becomes a contingency - forecasting becomes a far more problematic enterprise.”

The Landscape of History, John Lewis Gaddis (2002: 56)

Author's Note:

Flyvbjerg comments on the exemplar value of case study research: *“Common to all experts, however, is that they operate on the basis of intimate knowledge of several thousand concrete cases in their areas of expertise. Context-dependent knowledge and experience are at the very heart of expert activity. Such knowledge and expertise also lie at the center of the case study as a research and teaching method or to put it more generally still, as a method of learning. Phenomenological studies of the learning process therefore emphasize the importance of this and similar methods: It is only because of experience with cases that one can at all move from being a beginner to being an expert. If people were exclusively trained in context-independent knowledge and rules, that is, the kind of knowledge that forms the basis of textbooks and computers, they would remain at the beginner's level in the learning process. This is the limitation of analytical rationality: It is inadequate for the best results in the exercise of a profession, as student, researcher, or practitioner.”*

Bent Flyvbjerg 2006

The data for this investigation of practice relies on case histories along with other mixed methods research to study one such exemplar of expert activity arising from the product design and development cases documented in the Appendix. Case Study is a research method used to study a particular phenomenon, in this instance to answer the question of how design creates new value and competitive advantage in commercial marketplaces. Case Histories are the detailed record of the events and information associated with the case. The latter are a straightforward elucidation of what was done and why, with a modicum of reflection. Whilst the former are analytical studies that link historical events to theory, both existing and in relation to the study.

The quantitative and qualitative data of the cases in the appendix provide sourced, organised and compiled narrative chronological histories of the cases. This context-dependent data of the events provides the details and objective support for the research evidence. A synthesis of this case study research founded the insights that created the contribution to new knowledge for this thesis. Readers unfamiliar with the new product design and development process may find it beneficial to begin the reading with the narrative case histories before undertaking the thesis as a way of familiarizing themselves with the subject matter prior to reading the thesis.

Dan Brown 2017

Table of Contents

1. Introduction – a Research of Practice Journey	13
1.1 Explanatory Theory Arising from Exploratory Engaged Scholarship	21
1.2 Chronology of a Reflective-Design Practice	23
1.3 Reflection in and on Experience and Action-Supported Learning.....	25
1.4 Managing Bias in Reflective Practice Research.....	26
1.5 Case Histories' Archival Evidence as a Source of Data.....	28
1.6 Proven Market Viability – the Objective Evidence of Advantage	29
1.7 Competition's Role in the Evolution of New Value Creation	30
1.8 Design-Based White Space Strategy	32
1.9 Technically Rational Roadmaps Versus Design Inquiry Heuristics.....	33
1.10 Academic Rigour Arising from Autobiographic Narrative Research.....	35
1.11 Overall Aims and Objectives of this Doctoral Research.....	36
1.12 Glossary of Terms	37
2. Literature Review – Introduction.....	42
2.1 The Design Quest is Part of What Makes Us Human	43
2.2 The Dichotomy of Defining a Design Body of Knowledge.....	45
2.3 Etymology of Design – Seeking a Common Meaning	47
2.4 The Knowledge Gap in Practice	48
2.5 Design Certainty – Creating New Competitory Knowledge.....	50
2.6 Evidence Based Ontology and Epistemology of Design	52
2.7 Cognitive Dual Processing - Designerly Approach to Problems	53
2.8 Creative Synthesis – a Dialectic Whole Brained Designerly Process	53
2.9 Application of the Dialect Modelling to New Product Problem Solving	55
2.10 A Common Meaning and Definition of Design	57
2.11 Design Thinking – Designerly Creative Enquiry in Practice	58
2.12 Business Seeks Design-Based Competitive Advantages	59
2.13 Paradigm Change - Addressing Stakeholder Endowed Beliefs	61
2.14 Competitive Advantage Is the Driver of Business Advantage	63
2.15 Strategic Designerly Enquiry as the Creator of Competitive Advantage.....	65
2.16 Designing Customer-Getting Competitive Advantage.....	67
2.17 Design Differentiation Research into the Opportunity White Spaces	68
2.18 The Metric of Product Design Innovation Is Competitive Advantage	70
2.19 Literature Review Conclusion.....	72
3. Methodology Introduction – Rigour in Reflective Practice.....	73
3.1 Research Design – Summarizing the Study.....	74
3.1.1 Context for the Research of Practice Methodology.....	74
3.1.2 Patents as One Source of Primary Quantitative Objective Data.....	74
3.1.3 Competitive Advantage is a Quantitative Objective Evidence	75
3.2 The Theory and Practice Dichotomy in Design	75
3.2.1 Summary of Pragmatism Methodological Paradigm	78
3.3 Pragmatism in Design Practice and the Research of Practice.....	80

3.3.1	Pragmatism in Other Doctoral Design Studies	81
3.3.2	Autobiographic Practice-led Nature of Researching Practice	82
3.4	Research Plan Built on Case History Protocol	84
3.4.1	Axiology of Study	84
3.4.2	Ontology of Study	86
3.4.3	Epistemology of Study	87
3.5	Case Study as the Primary Research Method	88
3.5.1	Three Cases on New Product Design in the Marketplace	91
3.6	Case History Evidence in Support of Case Study Validity	91
3.7	Establishing Validity into the Case Study Protocol	93
3.8	Triangulating the Data Sources for Case Development Evidence	95
3.8.1	Market Data as a Quantitative Data Source	95
3.8.2	Historical Patent and Market Data as a Quantitative Data Source	95
3.8.3	Informant Interviews as Sources of Evidence	96
3.9	Grounded Theory	96
3.9.1	Grounded Theory Process Coding as a Method	98
3.10	Abductive Logical Enquiry and Reasoning	100
3.11	Methodology Conclusion	102
4.	<i>Insights Emerging from the Research of Practice - Introduction</i>	103
4.1	Researching the Practice – Design Relationship in Disciplinary Practice	103
4.2	Three Product Cases Creating Value and Advantage	105
4.2.1	Case One – Insta-Flow Dispenser Case	105
4.2.2	Case Two - Anti-Crossover Nozzle Case	107
4.2.3	Case Three - Creation of the Bionic Wrench Case	109
4.3	New Product Design Evolving Themes, Practice, Teaching, and Research	113
4.3.1	Course Themes – Heuristics of a Reflective Design Practice	115
4.3.2	Supporting Data from Informant Interviews – Thematic Analysis	116
4.4	Heuristic Process Themes for New Product Design	119
4.4.1	Design is an Innate Human Exploratory Research Quest	121
4.4.2	Designerly Enquiry is a Competitory Dialectic Synthesis and Reflection	122
4.4.3	Competitive Evolution Drives the White Space Quest for New Knowledge	123
4.4.4	Stakeholder Expectations Continue to Rise in a Competitive Environment	124
4.4.5	Opportunity Spaces (White Spaces) Exist Throughout the Product Experience	125
4.4.6	Bringing Strategic Focus to Unmet, Undermet, and Unarticulated Needs	126
4.4.7	New Product Value Creation Requires Empathic Framing and Re-Framing	127
4.4.8	Stakeholders Have a Bias for those Experiences They Know and Trust	128
4.4.9	Design Enquiry is a Qualitative Method on par with the Scientific Method	129
4.5	Research Heuristics	130
4.5.1	Bring a Root Cause Focus to the Problem Finding and Framing Challenge	130
4.5.2	Existing Market Benchmarks Provide the Competitory Reference for Research	131
4.5.3	Competitory Economic Benchmarks Provide Judgement Metrics to Research	132
4.5.4	Both Internal and External Stakeholders Influence the Design Research	133
4.5.5	Need Finding of Functional Drivers Often Provide Product Basing Opportunities	134
4.5.6	Need Finding Beyond Form and Function in the Unexplored White Spaces	135

4.5.7	Patent Research Provides Insights into Functional and Protected Technology	136
4.5.8	Research the Unexplored White Spaces for Seeking Competitive Advantages	137
4.6	Analysis Heuristics	138
4.6.1	Stakeholders Can Only Explain What They Believe to be True	138
4.6.2	Frame & Re-Frame the Stakeholder Needs Beyond What You Hear and See	139
4.6.3	Analysing Which Differentiators Add Value Across the Consumption Chain	140
4.6.4	Strategically Analyse Multiple Value Creators for Your Solution	141
4.6.5	Integrate Intellectual Property Analysis into Your Design Novelty Seeking	142
4.6.6	Novel Identity Analysis, Experience, and Awareness for Branding	143
4.7	Validation Heuristics	144
4.7.1	Stakeholder Choice Validation is the Experimental Laboratory for Designers	144
4.7.2	Employ Methods to Objectively Determine if You Meet the Design Requirements	145
4.7.3	Validate the Performance Metrics Through Rigorous Testing to Standards	146
4.7.4	Validate the Safety and Compliance with Industry Standards and Regulations	147
4.7.5	Validate the Business Model Strategy-Viability and Commercial Sustainability	148
4.8	Concluding Reflection on the Data	149
5.	<i>Synthesis from this Research of Practice - Introduction</i>	152
5.1	Purpose of This Research	152
5.2	Summary of Research Protocol Used in this Study	153
5.3	Addressing the Five Research Questions of this Thesis	154
5.3.1	New Knowledge-Based Problem Solving Drives Design Practice	154
5.3.2	New Value Benchmarks Require Strategic Re-Framing	155
5.3.3	Strategically Designing for Differentiating Competitory Advantage	157
5.3.4	Not all Design Opportunities Create and Sustain Value Equally	158
5.3.5	Differentiation by Design Strategy - the “How” of Competitory or Design Thinking	160
5.4	Recognizing the Strategic Drivers of the New Product Design Process	161
5.4.1	Stakeholder Choice – the Benchmark of Commercial Viability	161
5.4.2	Strategically Connecting Multiple Unexplored White Space Opportunities	161
5.4.3	Commercial Viability is the New Product Benchmark of Competitive Advantage	162
5.4.4	Strategic Competitory Thinking the New Competitive Reality	163
5.5	The CAM Knowledge Framework – Practice - Design - Compete	165
5.5.1	Design Projects are Different from Practice Projects	165
5.5.2	The Practice Knowledge Cycle Model	168
5.5.3	The Design Knowledge Creation Cycle Model	170
5.5.4	Practice and Design Co-Exist in a Practice-Design Model	171
5.5.5	New Design Competitory Dynamic Model	172
5.5.6	The Competitory Action Model as a New Knowledge Framework	173
5.6	Contributions of the Research	175
5.6.1	Summary of New Knowledge Contributions	176
5.6.2	Semantic Contributions of this Research	177
5.6.3	Methodological Contributions	177
5.7	Limitations of the Research	178
5.8	Next Steps for Future Research	179
5.8.1	Further Research Pathway One	180

5.8.2	Further Research Pathway Two	180
5.9	Concluding Remarks	183
List of References		184

List of Figures

Figure 1-1:	Expectation Bar Continues to Rise, and Change Becomes More Challenging	14
Figure 1-2:	Reflective Practitioner Researching and Reflecting on His Own Work	16
Figure 1-3:	Product Design Encounters Stakeholders Each Having Endowed Product Preferences	19
Figure 1-4:	Practitioner-Academic Dual Role in Engaged Scholarship	21
Figure 1-5:	Designer on a Similar Explorative-Explanatory Quest for New Knowledge	22
Figure 1-6:	Chart of Researcher's Career and Relationship to the Three Cases of the Study	24
Figure 1-7:	Reflective Researcher Weighing the Evidence as a Check and Balance for Bias	27
Figure 1-8:	New Knowledge Evolves by Design in a Strategic Competitory Evolution of Thought	31
Figure 1-9	Researcher on a Design Quest for the Unexplored Contribution to New Knowledge	33
Figure 2-1:	Hegelian Dialectic Modelling of a Designer Strategic Creative Thought Process	55
Figure 2-2:	C-K Theory Model (Hatchuel 2008: 182)	56
Figure 2-3	Design is How Business Strategically Creates New Opportunities	61
Figure 2-4:	Porter Five Forces Graphic, <i>Harvard Business Review</i> 2008	63
Figure 2-5:	MacMillan Consumption Chain Example	69
Figure 3-1	Case History Organizational Protocol and Framework Created by Author	90
Figure 3-2	Coding, from <i>Doing Qualitative Research Using Your Computer</i> (Hahn 2008: 15).....	99
Figure 3-3	The Abductive Research Process www.emeraldinsight.com	100
Figure 4-1:	Taken From Insta-Foam Products Sales Sheet (1985) – Depicting Three Kit Sizes	105
Figure 4-2:	Patent Drawing of Nozzle Design Brooks and Heinzl 1978).....	109
Figure 4-3	Differentiation by Design Course Thematic Analysis Arising from Reflective Practice ...	115
Figure 4-4	Designer on an Explorative Creative Quest for New Knowledge in Practice	121
Figure 4-5	Designer in Competitory Reflection in Action - a Dialectic Mental Modelling Process	122
Figure 4-6	Designer Seeking the Knowledge Gaps and Mentally Model the Possibilities.....	123
Figure 4-7	Stakeholders Expectation Benchmarks Continuously Rise in New Product Design	124
Figure 4-8	Designers Seeking Multiple White Space Value Creating Opportunities	125
Figure 4-9	Seeking Unmet Needs Brings Focus to Potential New Value Creation.....	126
Figure 4-10	Designers Must View Problems From Multiple Internal Stakeholder Perspectives	127
Figure 4-11	Designer's Focus on Attractive Value Propositions to Attract Customers	128
Figure 4-12	Strategically Viable Designerly Execution as a Rigorous Systematic Process	129
Figure 4-13	Can You Identify the Root Cause of the Problem, or Only the Symptoms?	130
Figure 4-14	Research Beyond Traditional Marketing Research of Consumption Chain	131
Figure 4-15	The Design Must Also Analyse the Value Judgement Benchmarks of Stakeholders ...	132
Figure 4-16	Stakeholders are Both Internal and External Participants and Judges of Success.....	133
Figure 4-17	Design Journey is a Need Finding Puzzle Interacting with Many Stakeholders.....	134
Figure 4-18	Strategically Focus on Value Creation throughout the Consumption Chain.....	135

Figure 4-19 The Design Journey Must Also Benchmark the Existing Knowledge Solutions	136
Figure 4-20 Designers Seek the Unexplored White Spaces for New Opportunities	137
Figure 4-21 Designer as Researcher Diagnosing the Stakeholders' Needs.....	138
Figure 4-22 Empathically Frame and Re-Frame Needs beyond Existing Conceptualizations	139
Figure 4-23 Needs That Can Add Value Must be Identified in Order to Bring Focus to the Project .	140
Figure 4-24 Designers Seeking Opportunities Throughout the Consumption Chain	141
Figure 4-25 Commercial Sustainability Requires a Designerly Intellectual Property Integration	142
Figure 4-26 Brand Identity is Designed Early in the Process Reflecting the Designed Advantages	143
Figure 4-27 Validating with Stakeholder is the Laboratory of the Designer's Research	144
Figure 4-28 Stakeholder Validation is the Metric of Competitory Design Practice.....	145
Figure 4-29 New Design Requires Best Practice Performance Validation	146
Figure 4-30 New Design Requires Best Practice Standards and Safety Compliance Validation	147
Figure 4-31 New Design Requires Best Practice Business Model Validation	148
Figure 5-1: Design of the Woodpecker Drill (Singh 2014).....	157
Figure 5-2: The Practice Knowledge Cycle	168
Figure 5-3: The Design Knowledge Cycle and Heuristics of the Design Process	170
Figure 5-4: The Practice – Design Co-Existent Relationship – Creating New Knowledge	171
Figure 5-5: The Recognition That Not All Newly Designed Knowledge is Competitive	172
Figure 5-6: Competitory Action Model (CAM) – Creating New Knowledge (Author)	173
Figure 5-7 Possible Applications of the CAM Frameworks for future Research	182

List of Tables

Table 3-1: Chart From Milman (2010).Class on Qualitative Research Course Slides	79
Table 3-2: Stompff Thesis "Overview of Relevant Scientific Paradigms" (Stompff 2012: 44)	81
Table 3-3 Thesis Philosophical Foundation Chart	82
Table 3-4 Organization and Development of the Case Studies.....	89
Table 3-5: Yin Six Sources of Evidence for Case Study Methods (Yin 2014: 106)	92
Table 3-6: Case Study Tactics for Four Design Tests (Yin 2014: 45)	93
Table 3-7 Correlating Yin Criteria with this Thesis Case Study Criteria.....	94
Table 3-8: Methodological Paradigms demysqualitativeresearch.blogspot.com	97
Table 3-9 Thesis Grounded Theory Chart.....	97
Table 3-10 Methodology Summary Chart Designed and Created for this Thesis	102
Table 4-1: Summary of Emergent Themes from Interviews	197
Table 5-1: Design Project - Challenge Versus Practice Project-Challenge Comparison	167

1. Introduction – a Research of Practice Journey

An investment in knowledge pays the best interest

Benjamin Franklin

The findings and insights revealed in this reflective-practice-led thesis summarise thirty-plus years of design actions and experience in the marketplace. This practice has informed my philosophy of design and thinking of how product design creates value and competitive advantage in markets. In the following sections, I will discuss this practice-research journey and the three cases I have chosen for this study. Researching one's own practice or design work (auto-ethnography) always raises the question of bias created by the researcher's lack of objectivity. In an effort to avoid and manage bias for this study, the reflective insights focus on commercially available products that have histories of design, patent, market, and first-person informant data to support the author's reflective narrative of the process.

The research data that emerges from cases representing business-to-business (B2B) as well as business-to-consumer (B2C) products are represented, the difference being who your end customer is (are you selling to the consumer or another company)? These product cases were originally designed for SMEs (small manufacturing entities), and each established a new, patented technology in a growing competitive market. A large multinational corporation acquired the technology of cases one and two, and now is bringing those products to market. For evidence of successful new product design, I rely on the competitive marketplace and proven market viability as the objective arbitrators of value and advantages arising from the respective competency design processes of the three case histories.

It is my perspective that case data deriving from the design of products that have proven market competition is quantifiable evidence of performance. Acknowledging that all product design experiences have different levels of competition, as some successful new products result from breakthrough technology. Breakthrough technologies often enter market spaces by virtue of their technology advancements, not from their comparable product design advantages with existing solutions. Conversely, mature product categories that have had a significant number of competitive battles exhibit many iterations of design improvements, often escalating the performance expectations of the stakeholders and creating challenges for designers to design new value in these circumstances (see Figure 1-1).

When stakeholder preferences and expectations occur through evolutionary iterations, the comparative bar rises for new product entrants. The designer's challenge also rises to meet or exceed these escalating competitive benchmarks. For example, the first websites after the internet evolved to allow graphic images were crude and expensive by today's standards. Each year the quality and efficiency of using graphics on the web increased as the cost to achieve them decreased. Seeking to create a new competitive experience in this well-travelled area is much more challenging today after the expectation evolution than it was in those early website creation days. Thus, product designers, in a competitory quest for seeking new value creation in these circumstances, must focus on opportunity spaces for creating and sustaining competitive advantages in the marketplace.

The performance escalation that occurs in competitive-market situations is a significant challenge for new product design that seeks new competitive advantages. These competitive forces dictate the paradigm in which the practitioners of new product design and development find themselves when seeking to create advantage and compete in the marketplace. Thus, products that dominate in the face of this competitory dynamic can claim competitive advantage often arising from their designed advantages. Through the research of practice, this study explains the process of how designers can seek, identify, and create new competitory advantages in these often highly competitive expectation-escalated situations in the marketplace.

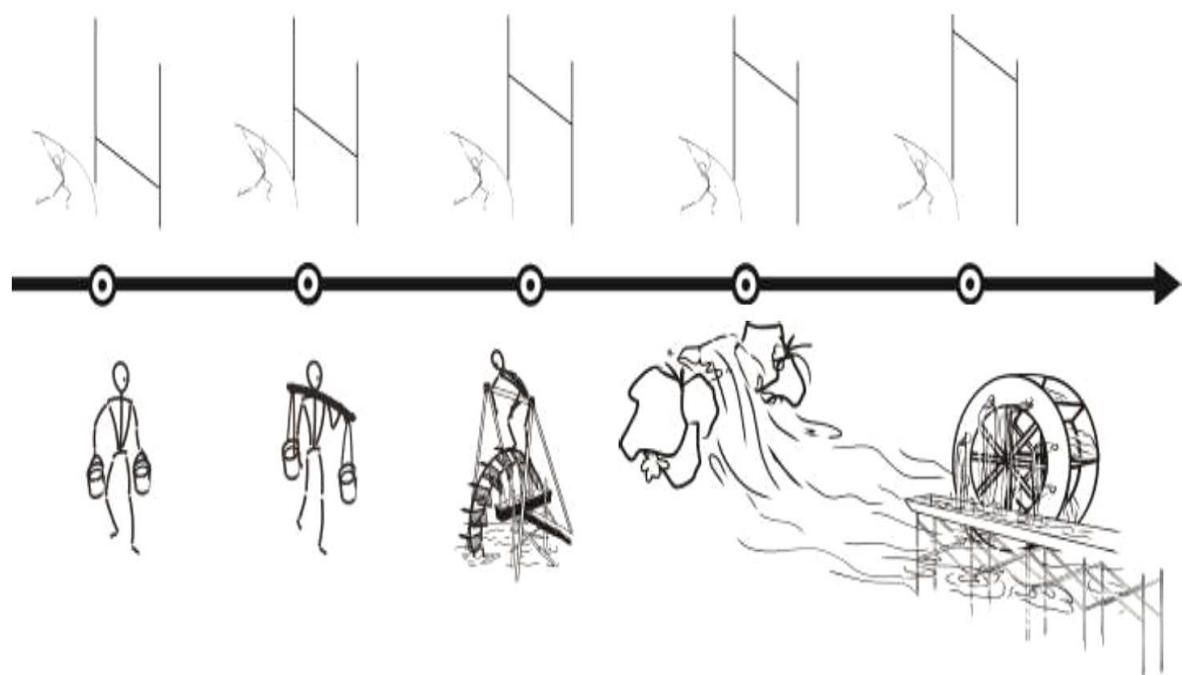


Figure 1-1: Expectation Bar Continues to Rise, and Change Becomes More Challenging

Focusing on the strategic actions of how design creates new value and evolutionary change in business, the explanatory lens of “practice-led” academic research provides the framework for researching the three cases, and new academic explicit knowledge contribution has emerged. Practice-led evidence-based cases of practice are challenging but not new, as Flyvbjerg states: “case study has its own rigor, different to be sure, but no less strict than the rigor of quantitative methods. The advantage of the case study is that it can “close in” on real-life situations and test views directly in relation to phenomena as they unfold in practice” (Flyvbjerg 2006: 19). Thus, a distinction is that this is not “practice-based” design research, wherein the focus is more on the designed artefacts or outcomes of a creative project as in art or dance research. Rather, this effort builds on an explanatory-based academic research arising from the knowledge of “real-life” design process evidence provided by the chosen case histories.

Reflectively studying these cases places me in a unique autobiographic research position: a first-person reflective lens seeking theory from those “real life” actions and experiences of past practice. Dewey, a noted thought leader and education philosopher has articulated the role of reflection on experience in learning in *Democracy and Education*. “When we reflect upon an experience instead of just having it, we inevitably distinguish between our own attitude and the objects toward which we sustain the attitude ... Such reflection upon experience gives rise to a distinction of *what* we experience (the experienced) and the *experiencing*—the *how*” (Dewey 1916: 195–96). Reflective-practice research is a reflection upon actions and experience methodology, employing a research protocol, seeking to explain how the design process of the chosen cases created competitive advantage.

A possible secondary outcome of this study springs from the research design protocol itself, specifically the methodology of a reflective practice of one’s own work. After many years of exploratory design practice, and having achieved some market and commercial success, I am in a unique research position. Schön established the academic credibility of reflective practice as a rich source of evidence-based data arising from expert practice. This study builds on the Schön philosophy and principles of reflective practice as depicted in Figure 1-2. In addition, my uncommon role of a mature practitioner-researcher investigating the practice of his own work is possibly unique in design practice research. Therefore, the design for the protocol has itself been a research process for identifying the correct methods and methodology in

support of the autobiographic nature of researching one's own design work and practice. The methodology for this study is discussed in detail later in Chapter 3.

Building on Schön's reflective practice, this study encompasses an explanatory evolution of work stemming from an exploratory past practice. Not all research is the same: "The fundamental philosophical difference between exploratory and explanatory research is ontological. In explanatory research the phenomenon to be studied already exists out there, and the goal of the researcher is to develop an understanding of it. In exploratory research and design science, in contrast, the phenomenon must be created before it can be evaluated; the creation of *artificial phenomena* ... or simply *artifacts* (e.g., technologies) is essential" (Holmström, Ketokivi, and Hameri 2009: 68). Thus, while my practice did create significant product artefacts in practice, this research will focus not on the artefacts, but rather on the explanatory process of designing and strategically creating those artefacts.

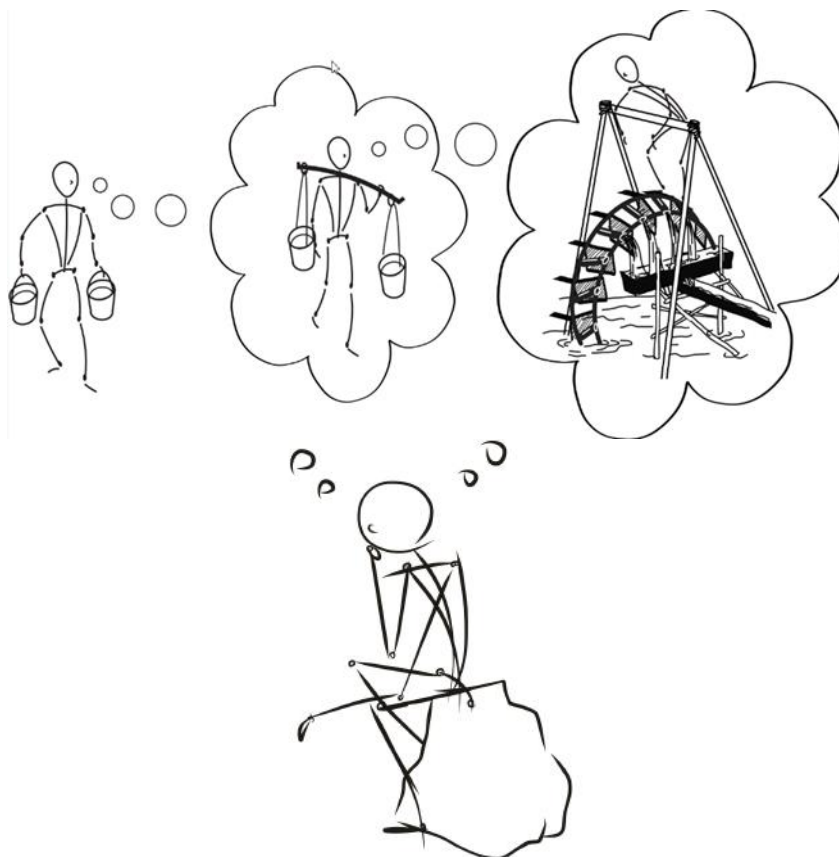


Figure 1-2: Reflective Practitioner Researching and Reflecting on His Own Work

In support of the research into this process are my reflective insights and archival quantitative data in the form of patents, artefacts, and business information, all of which combine to support the research-designer reflections. In addition,

interviews of informants with first-hand knowledge and direct involvement in the three cases support the data. Market viability reasoning, that is, products that have competed and stood the test of time in competitive marketplaces share the unquestionable distinction of being value creators with proven competitive advantages. Therefore, beyond the artefact-based historical development data derived from the creative action of the design process, the cases have subsequent market metric data. Arising from real world market competition, the resulting product performance provides the quantitative logical standard for the reasoning.

Having now completed this research of my past practice, I discovered that a design challenge emerges in practice when the existing domain knowledge of practice is insufficient to solve the problem at hand. This knowledge gap challenges the practitioner to seek new knowledge to provide a suitable solution or abandon the effort. These are often situations where practitioners find themselves challenged by new and vexing problems not encountered, or previously unsolved, in prior practice. Practitioners must often seek new solutions in uncharted areas of their disciplines or outside their disciplines as the existing best practices often failed. Reflecting on my past practice, as seen in the case histories, I realised that, when confronted with this vexing situation, I required my mindset to mentally morph from a practitioner of existing knowledge to a seeker of new knowledge as I struggled to design the solution.

Recognizing that there are ranges of design outcomes, and that not all new designs can contend, the ability to compete is fundamental to the product success. The explanation for this is that a design may be a new knowledge embodiment, and not all new embodiments actually meet or exceed the endowed stakeholder benchmarks that define new value, as many new products fall short of competitiveness in any number of areas. Designing new knowledge that successfully contends with the existing knowledge of a stakeholder's paradigm requires a big-picture understanding of the existing competitive dynamics. This competency benchmarking research of the whole product experience is necessary to inform the transactional design decisions and trade-offs throughout the design process. This challenge of creating competitive advantage complicates the product design process requiring a strategic design approach, purposefully bringing focus to the strategic practice of design research, analysis, synthesis, and validation heuristics of the process for creating advantage.

Having bridged this gap numerous times, I found in my design practice that the advantage often sought by business is complicated by a stakeholder-endowed bias for the existing solution. In his book *The Structure of Scientific Revolutions* (Kuhn 1970), Kuhn articulates this existing stakeholder resistance to change as the competitive dynamic of a paradigm shift. He explains that, when a new knowledge proposition displaces existing stakeholder preferences, there is a paradigm shift. Kuhn focuses on the evolution of scientific knowledge, and how the dynamics of the existing paradigm stakeholder's preferences act as a check and balance to the unwarranted new knowledge adoption of a discipline. This knowledge competition judged by paradigm stakeholders is a competitory knowledge evolutionary process.

In the marketplace, product stakeholders have similar paradigm biases formed by pre-existing value expectations and preferences. These expectations and preferences must dominate the designer's researching of objectives and requirement benchmarks if the new product designer hopes to compete for the stakeholders' choice. Product designers seeking marketplace acceptance of their new products confront this stakeholder-paradigm change dynamic; often it must be the design objective to change the stakeholders' endowed bias. As in Kuhn's articulation of the challenge of paradigm change and stakeholder acceptance in science, similar change phenomena exist for new products in the commercial marketplace.

Kuhn's model, which exemplifies the stakeholder judgement challenge for new knowledge propositions, finds its parallel in the marketplace. Existing product preferences often act as a check and balance for new product knowledge, contributions, and acceptance in the marketplace. This competitory dynamic interplay between new knowledge and existing knowledge (or new products and existing products) for the stakeholder's choice is the behavioural judgement-economic model I adopt.

Designing new value and overcoming the stakeholder preference (or existing endowed bias) and at the same time establishing a new bias for your solution is the battlefield between new product entrants and the existing stakeholder preferences. These competitory judgements act as the true metrics of value creation as judged by the stakeholders who choose what products deserve their purchasing behaviour and what products do not in a competitive marketplace (see Figure 1-3).



Figure 1-3: Product Design Encounters Stakeholders Each Having Endowed Product Preferences

A premise holds that when a practitioner confronting a knowledge gap seeks to create new knowledge, where existing knowledge of practice falls short, he is designing. If the product created by design competes for and wins the preferences of the stakeholders, this is the benchmark metric of what competitive advantage in new product design is about. From my experience winning the choice indicates that the designer has strategically identified unmet and unarticulated stakeholder needs in the process. Design enquiry researches insights into these needs, bringing focus to the designer who is seeking to create new value and competitive advantage in the marketplace. This design process is critical to commercial business competitive success.

Professionally, I am a designer, inventor, entrepreneur, and professor of design. Arriving at this point has been a lifelong knowledge quest (see Figure 1-5), and knowledge seeking has always been a part of my personal design ethos. My curiosity has continually motivated me to understand concepts, to know what I did not know, in what I now recognise as an innate designerly quest for knowledge, whether solving a problem in the marketplace, or now, through this research. In this academic researcher role, I have synthesised and articulated explicitly what I have learned in practice and academically through teaching.

Most notably, I am still a student of life, pursuing a lifelong goal of earning a Ph.D., fortunate enough to have the opportunity to do so in design, my professional life's experience and passion. This academic research has been a very challenging exercise in a number of ways. I have had to release myself from the comfort zone of all my years of practice-based, tacitly formed knowledge. Now as an academic researcher, I have embraced a new paradigm of explanatory knowledge seeking

through my past design. This new paradigm has evolved from my academic work as a clinical professor focused on teaching and from the desire to create an academically researched theory to support my knowledge acquired in practice. I have also found academic research in the discipline of design itself to be a significant challenge. First, existing-design, reflective-practice-based research to build from is scarce. Second, the semantic positioning of where design fits into the taxonomy of academic disciplines, as well as the disciplinary knowledge of design's role in the academic philosophy of knowledge contribution, is still evolving.

To summarise, this thesis explains how new-product practitioners strategically seek (designerly enquiry), conceive (dialectic analysis) and create (creative synthesis) new product value and competitive advantage in practice. In business, the prevailing challenge of new product design and development is the commercial viability of that new advantaged knowledge. Competitive advantage requires insights into the competency dynamics and judgement drivers of the stakeholders. These insights are the result of a thorough researching of the situation, first benchmarking the existing knowledge space as a platform to seek a new advantaged knowledge space. This design research has a dynamic interplay with disciplinary practice.

In practice, following a traditional disciplinary path, practitioners (engineering, medicine, education, etc.), confront situations where the existing best practice knowledge of the discipline falls short in practice, whereby a knowledge gap condition presents itself. At this junction of disciplinary practice, the practitioner must then pioneer a new pathway to overcome this knowledge gap. Cognitively transforming, the practitioner shifts approaches to the challenge, becoming a designer in practice. This shift calls upon a designerly, exploratory methodology of practice that exists in all of us at a basic level, co-existing with our rational analytical human natures. In situations where the knowledge gap exists, the proficient practitioner-designer employs this exploratory enquiry skilfully, employing designerly methods to research, analyse, and conceive competency strategies to fill the knowledge gap at hand.

As my design journey has continued to evolve through this academic research of past practice, my perspective of design has both deepened and expanded to where I now feel confident in proposing an enhanced meta-definition of design arising from academic research, a definition that I support through the literature review and semantically argue further in Chapter 2. That new definition is:

Design is how humans seek, conceive, and create new knowledge.

1.1 Explanatory Theory Arising from Exploratory Engaged Scholarship

To practice without theory is to sail an uncharted sea; theory without practice is not to set sail at all.

Mervyn Susser, *Community Psychiatry*

From Practice to Theory through Engaged Scholarship

The research objective is to contribute new theory for the design process, supported by the evidence-based research of practice. Van De Ven addresses this from several points of view in the article “[Knowledge for Theory and Practice](#)”, in which he and his co-author Johnson attempt to understand the nature of this exploratory and explanatory research dynamic, stating that, “[To bridge the gap between theory and practice, we need a mode of enquiry that converts the information provided by both scholars and practitioners into actions that address problems of what to do in a given domain—thus, our proposed method of engaged scholarship is a means of creating the kind of knowledge that is needed to bridge this gap](#)” (Van De Ven and Johnson 2006: 803). The authors discuss the role and fundamentals of engaged scholarship, as a method to bridge this theory-practice gap through an academic mode of enquiry. Confronting this theory and practice gap dynamic as a designer, an academic, and now a researcher in this study, I am embracing the engaged scholarship form of enquiry and research (see Figure 1-4).

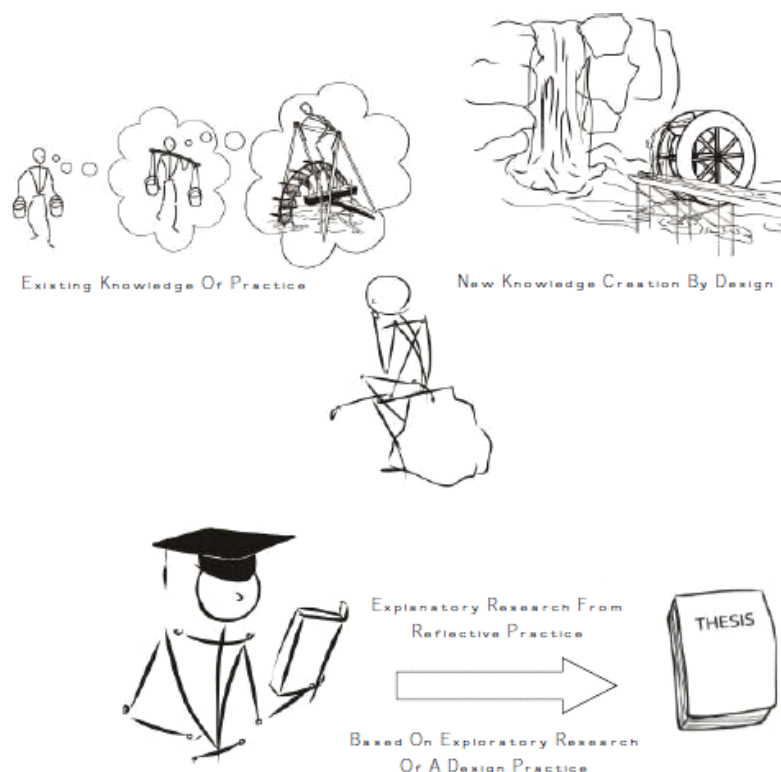


Figure 1-4: Practitioner-Academic Dual Role in Engaged Scholarship

Having created new theory from researching practice through this investigation and synthesis, I have now experienced both the practice and the theory of new knowledge creation. In this unusual dual role of theory and practice researcher, I recognise a similar knowledge gap dynamic in the academic research that I have experienced many times in design practice. On reflection, it is ironic that this research has itself constituted a form of an academic design project, whose objective is the contribution of new academic knowledge explaining the design process in practice. My past design practice shares a surprisingly similar set of heuristics with my academic research.

One aspect of this engaged scholarship experience that also stands out is a realization that new design knowledge contributions do not occur in a systematic step-by-step methodology. Similarly, I believe this is also true of the academic research process. On reflection, I have realised that both the academic research of this study and the design research of my practice share this heuristic-based research methodology in the quest for contributions to new knowledge. Whilst ultimately the proposition that both are similar design practices is beyond this study, the similarities between the two disciplines in the process of creating or contributing to new knowledge is seemingly more than a coincidence, posing the question: does academic exploratory research form an academic design process of enquiry (see Figure 1-5)?

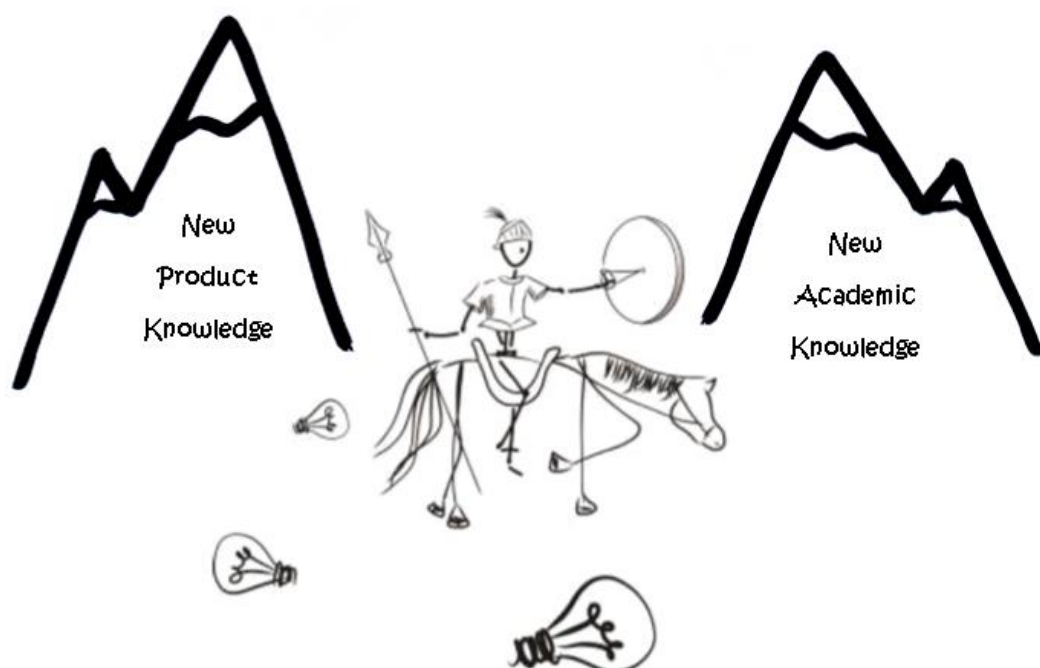


Figure 1-5: Designer on a Similar Explorative-Explanatory Quest for New Knowledge

1.2 Chronology of a Reflective-Design Practice

Design is the last great competitive advantage.

Scott Henderson

The summary and chart below represent my outcomes and timeline (see Figure 1-6) from college graduation in 1978 through today in a dual role as designer-academic researcher. The chronology takes the reader through the industry practice roles and responsibilities on the left of the timeline and the patents issued for completed design project work on the right. Highlighted in black are patents related to the three cases histories; U.S. patents for other work are in grey. Images of the products developed surround the respective patents, and there is a brief description of each case alongside the product image on the right. Further details of each case are located in Chapter 4, as well as the complete case histories for each case in the addendum.

Patent and Award Highlights of the Author's 30+ Years of Design Practice

- Thirty-five U.S. utility patents and several design patents issued
- Over one hundred U.S. and International patents combined
- Ten international design awards
- 2009 Popular Mechanics Breakthrough Innovation Award
- 2008 iF – International Forum Design Universal Design Award
- 2007 Plant Engineering Magazine (Bronze) Product of the Year
- 2007 iF International Product of the Year Award (second time received)
- 2007 Farm Industry News FinOvation Award, Award for Product Design
- 2006 Chicago Innovation Award, Chicago Innovation Award
- 2006 iF – International Forum Design Product of the Year – Gold Award
- 2006 Red Dot – Red Dot Product Design – Best of the Best Award
- 2005 Popular Mechanics Editor's Choice Award
- 2005 Chicago Athenaeum Good Design Award

Also, numerous articles and product media coverage

This is a sample of the awards and recognition for my new product development from later product designs. In my earlier design efforts, I found that although the products received industry awards, my clients received the design recognition as my role was often behind the scenes and covered by non-disclosure agreements. This situation was one of the reasons I chose to create a case study type project and fund it entrepreneurially (case history three) as I sought a tangible example of my process and the recognition of the design work of that process.

Chronology of Author's 35 Years of New Product Design and Development

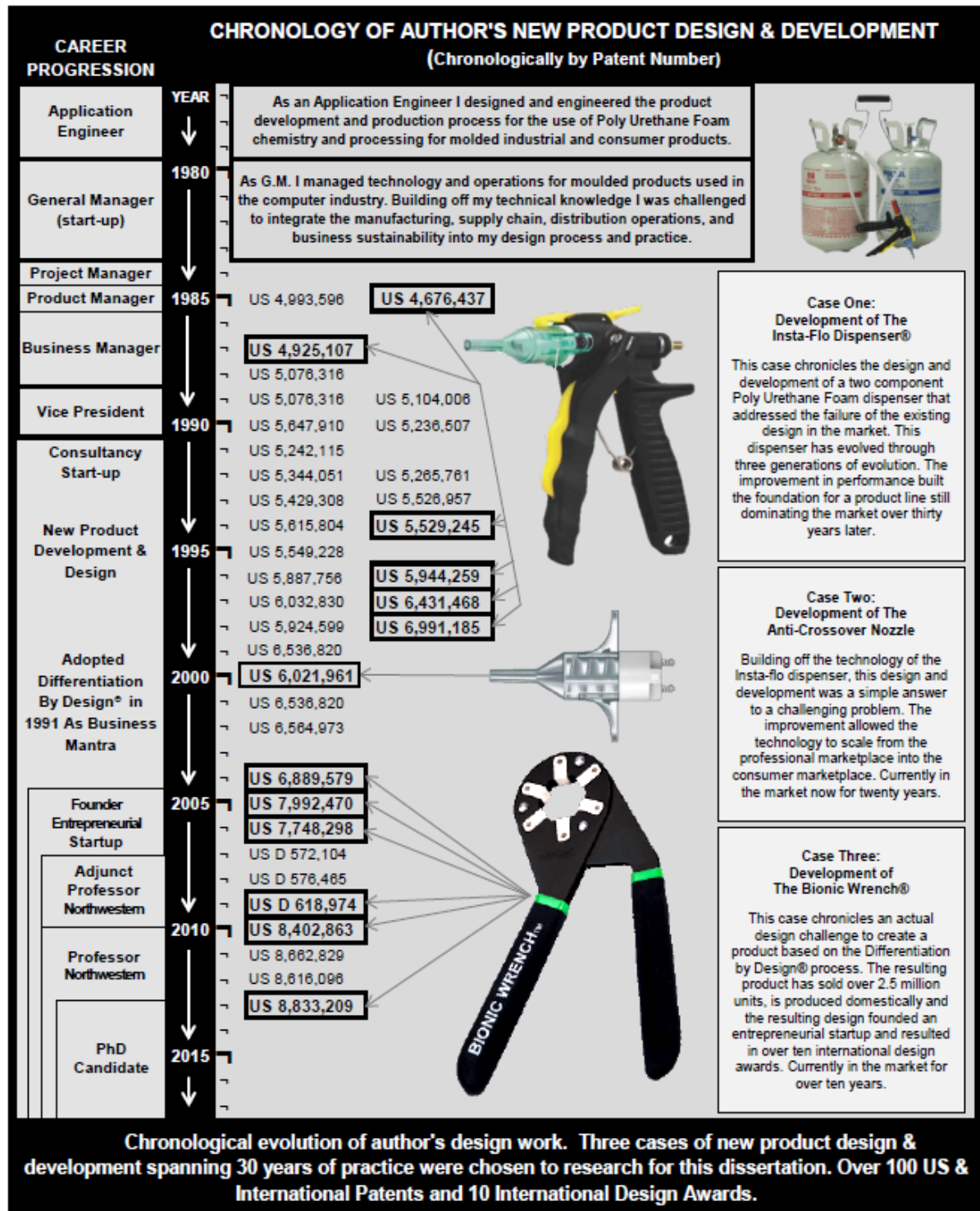


Figure 1-6: Chart of Researcher's Career and Relationship to the Three Cases of the Study

1.3 Reflection in and on Experience and Action-Supported Learning

The [reflective] practitioner allows himself to experience surprise, puzzlement, or confusion in a situation which he finds uncertain or unique. He reflects on the phenomena before him, and on the prior understandings which have been implicit in his behavior. He carries out an experiment which serves to generate both a new understanding of the phenomena and a change in the situation.

Donald Schön, *The Reflective Practitioner*

For the research of methodology, I rely on the work of many experts, but primarily the work of Donald Schön, author of *The Reflective Practitioner—How Professionals Think in Action*. His book is now a standard reference for several disciplines, most notably in education and healthcare that have embraced reflective practice as a cornerstone methodology of their research. Schön, now considered a significant thought leader by many, dedicated his academic life to the research surrounding reflection in its many forms as a cognitive retrospective analysis of a situation, as well as a personal form of dialectic debate and reasoning, applied to actions and experiences. Schön writes that, “a professional practitioner is a specialist who encounters certain types of situations again and again” (Schön 1983: 60). Furthering his position, he states, “As a practitioner experiences many variations of a small number of types of cases, he is able to ‘practice’ his practice” (Schön 1983: 60). A process Schön named “knowing in practice” is analogous to diagnosing measles in different patients, recognizing the symptoms of the illness tacitly through the knowledge the healthcare expert has acquired through experience with measles patients.

Knowing in practice as a form of knowledge in action can be directly applicable to new-product design practice. Often tacitly, proficient designers pursue knowledge through new pathways of product explorations through their actions. Says Schön; “Reflection-in-action, in these several modes, is central to the art through which practitioners sometimes cope with the troublesome ‘divergent’ situations of practice” (Schön 1983: 62). Although not stated as such by Schön, this author believes that this quote directly maps onto the wicked problem comparisons of the nature of design practice. Design by nature is an exploratory effort to understand these divergent problems, characteristically lacking a science-like technical rationality approach. This practice often appears as a mystery as to how the process of design researches, analyses, and synthesises solutions to those wicked divergent situations.

Whilst this knowing in practice cannot always be deductive and quantifiable, Schön and others have argued that it exists. Schön has also argued that this knowing in practice and its ability to be articulated and explained through practitioner reflection can lead to new knowledge in practice and, as pursued in this research of practice. This knowledge of practice can issue from action research, as the reflection immediately follows the event, or in a delayed analysis of reflection on action, where the analysis is in a post-mortem-type of reflection. It is the post-mortem reflection of the actions and experiences of practice on which this research relies (Schön).

The process of reflection focuses on the many design actions over the years of my practice, so it lacks the immediacy of data capture to support the reflection. Therefore, my reflections are subject to hindsight bias as well as confirmation bias in pursuing this research. Addressing this bias vulnerability as a potential challenge to this research validity, I have embraced an axiology (ethical standard) for managing the inherent bias. My argument for the methodological management of bias derives from the purposeful reliance on evidence-based objective data, organised and synthesised in detailed case histories supporting the reflective-research methodology.

1.4 Managing Bias in Reflective Practice Research

Our bias toward thinking blinds us to the non-logical processes which are omnipresent in effective practice.

Donald Schön, The Reflective Practitioner

Bias is an ever-present issue that all academic researchers and researchers in practice must consider and manage. The research design protocol relies on both qualitative and quantitative evidenced-based exploration of the design process to support objectivity. Although without question I acknowledge that one must constantly guard against bias in research I argue that the competition between products in commercial marketplaces offers quantitative and objective results for the three design cases I have selected. The thesis also relies on the logic that the three case histories chosen are competitively advantaged examples of new product design suitable for academic research. This competitive marketplace validation is at the heart of product or commercial design practice, competitive advantage being the metric of product design achievement in the competitive marketplace.

Reflective practice is subject to a form of bias referred to as hindsight bias. When reflecting on past actions, false memories, if not managed, can be an empirical trap. Whilst the subjective bias of a reflective researcher is no different from the bias all researchers bring to their work, a researcher's reflection narrative of his own work must acknowledge the potential for shaping the narrative to fit the thesis. This hindsight bias has been studied and reported on in psychology literature and defined by researchers Rehm and Gadenne as, "a phenomenon, where individuals know the outcome of some event and consequently judge that outcome as more likely than when they would not have that outcome knowledge" (Rehm and Gadenne 1990: 116). To guard against subjective hindsight bias, the new product design process data relied upon for this research has market tractability, designed artefacts, and patents as quantitative evidence-based data to support the development process reflections. Therefore, while reflection is always subject to hindsight bias, there is considerable historical evidence in the records, and the artefacts of the design practice presented in the case histories support the reflections. At the same time, the researcher must vigilantly manage bias throughout this research (see Figure 1-7).

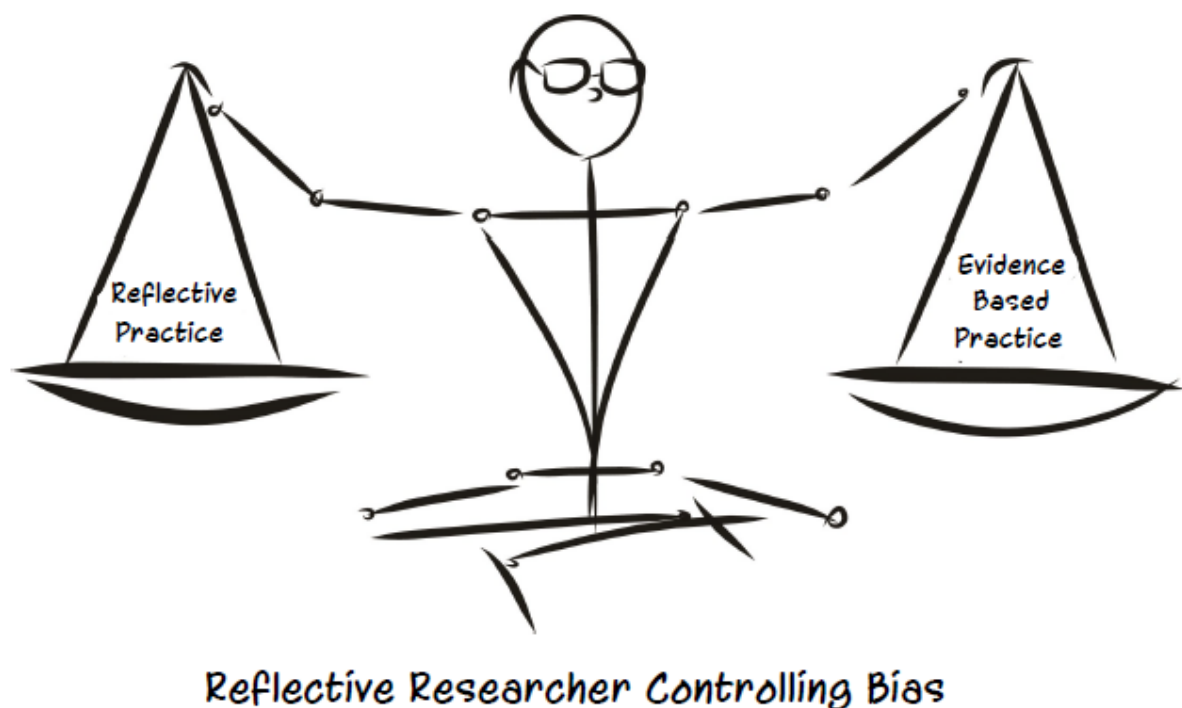


Figure 1-7: Reflective Researcher Always Weighing the Evidence as a Check and Balance for Bias

1.5 Case Histories' Archival Evidence as a Source of Data

For the things we have to learn before we can do them, we learn by doing them.

Aristotle, The Nicomachean Ethics

Case studies that derive from researching the invention journey of successful product cases in both the patent documents and the other market research associated with the product can combine to form a rich, instructional, and multi-dimensional context for researchers to learn from. Many of these patents communicate foundational novelty and insights of the inventive design journey. The ability to research case histories that contain this archival quantitative data provides insights into both the technology and the invention's prior art, as well as the developmental aspects of the design process. Carroll and Rosson comment on the value of using patents:

Case studies are descriptions of a specific activity, event, or problem, drawn from the real world of professional practice. They provide narrative models of real life to students and other novice practitioners. Cases incorporate vivid background information and personal perspectives to elicit empathy and commitment, and present contingencies, complexities, and often dilemmas intended to evoke integrative analysis and critical thinking. Cases engage the student in the drama of a real situation (Carroll and Rosson 2005: 1).

Development and invention stories of competitive practice in the marketplace have a journey that goes beyond the patent. Stories of competitive historical market data as well as the artefacts themselves provide resources available for analysis of the design-invention experience, although the focus on objective evidence is critical.

Currently there exist several full-text databases of U.S. patents going back more than a century, along with various levels of similar coverage for foreign patents. These databases are the collective repository of patent historical data for understanding the design process. Ozkul has concluded that, "Studying patents give [sic] the idea of 'know-why' which leads to understanding of intricate industry needs that leads to the particular invention. Every patent has a section on 'background' which explains the need for the invention. Studying and understanding these needs is the first step in finding the solution" (Ozkul 2008: 158). Investigating these archives provides a wealth of quantitative insights into the problem domain and past solutions addressed by the inventor, and each case history has patent data to draw from.

1.6 Proven Market Viability – the Objective Evidence of Advantage

Confirmation bias poses a potential problem when researching the condition of claiming a designed advantage and simply assuming or implying an advantage for the subject of the design case. This might happen when a researcher would claim an advantage that stems from action research where no actual real-market competition had taken place. Whilst the researcher of a new product process can follow a rigorous methodology, the assumption of a designed advantage claim without an objective measure of product success is unfounded. Hence, objective confirmation is enabled by successful marketplace performance. For evidence of designed advantage, the study uses independent checks and balances provided by marketplace stakeholders; market viability affirms the sustained and demonstrated competitiveness of the three designed products over time.

In the article “New Products: What Distinguishes the Winners?” Cooper states, “These winning products offered unique features not available on competitive products; they met customer needs better than competitive products; they had higher relative product quality; they solved a problem the customer had with a competitive product; they reduced the customer’s total costs; and they were innovative” (Cooper 1990: 27). Although the article is a bit dated, his theory still represents the design philosophy of creating competitive advantage embraced in business, and the foundational findings of the study are still relevant today. The key lessons of successful new products according to Cooper are:

1. The number 1 success factor is a unique, superior product.
2. A strong market orientation is critical to success.
3. Pre-development activities—the homework—are vital.
4. Sharp and early product definition improves the odds of winning.
5. New product success is controllable.
6. There are no easy answers to what makes a winner.
7. Companies that follow a new product game plan do better. (Cooper 1990: 30–31)

Cooper also emphasises that new product design will always be a high-risk endeavour, and I certainly agree. I also believe Cooper would agree that new product design does not have to be an arbitrary process, but instead is a strategic best-practice process built on a focused competitive strategy of creating advantage.

1.7 Competition's Role in the Evolution of New Value Creation

Beyond acting as the metric for objectivity when claiming new product value creation, competition plays a key role in the market. As a practitioner, I employed design-based value creation and problem-solving long before I viewed myself as a designer or recognised where my design abilities, honed in experience and practice, would take me. As [Friedman](#), a researcher and thought leader in the design field, noted:

Because design knowledge grows in part from practice, design knowledge and design research overlap. The practice of design is one foundation of design knowledge. Even though design knowledge arises in part from practice, however, it is not practice but systematic and methodical enquiry into practice—and other issues—that constitute design research, as distinct from practice itself. (Friedman 2003: 512)

As Friedman suggests, the design knowledge of this research of design practice and enquiry methods has directly evolved from the knowledge of creating competitive advantage in my design practice.

Reflecting on that aspect of my career, this reflection-based research of my practice has evolved from that tacit battle of practice in the competitive marketplace. The experience has led me on a professional-practice journey as an inventor, engineer, product designer, business manager, company officer, design consultant, entrepreneur, and clinical associate professor. I have always viewed design as a distinct process based on a personal ethos of creatively solving problems in a competitively advantaged way. I now find myself at yet another crossroads of this journey by academically researching my past practice, examining how this past work created new value and competitive advantage in the marketplace.

Researching my design practice has brought focus on the unique role of marketplace competition in practice and who determines what competitive advantage is. In practice, I learned quickly that multiple stakeholders arise in all areas of the new product experience and each has their own basis for judging the new product's value proposition. Although a designer may create a new, functional solution to the problem, the reality of success or failure is much more complicated. Success claimed solely by the designer is unfounded; the reality is that success represents the judgement of many stakeholders. Thus, this crowd of stakeholders and their judgements establish

a competitive metric of checks and balances of practitioner bias in the process of designing new value. Critical to a design's success is the research of these stakeholders across the consumption chain of the product experience, seeking need-based insights and a design strategy to address these stakeholder needs.

On reflection, my design success was dependent on the viability of my designed artefact to compete in the marketplace with other designs. Often these advantages go beyond the form and function of the product, creating value across a spectrum of stakeholder needs across the whole consumption chain of a product's experience. As markets evolve, successive design iterations also evolve, continually raising the competitive benchmarks.

Thus, the drive in new product design is to identify more advantage creation opportunities for designers (see Figure 1-8) as the product evolution dictates based on creating new competitive advantage. My ability to evolve as a designer required me to seek new forms of advantage wherever I could. I found that success grew by focusing on a broader stakeholder research process. Seeking new advantage creation opportunities forced me to look beyond those basic form and function needs of the stakeholders. Striking out in 1991 in my own new product design consultancy, I gave a title to this process – differentiation by design – that has been the mantra of my design work since then and the focus of this research of design practice.

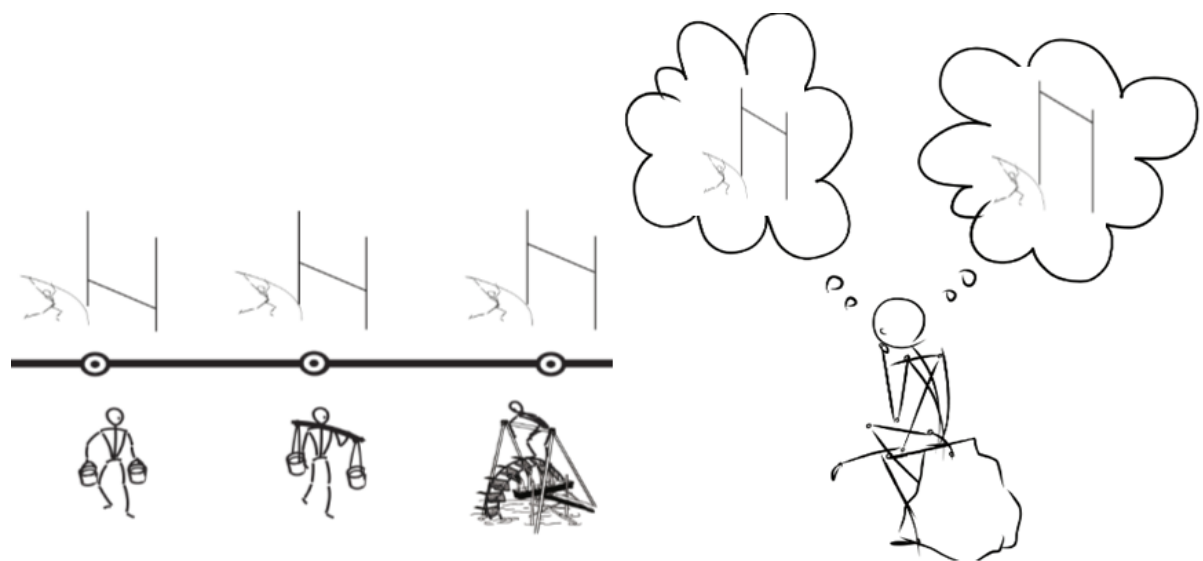


Figure 1-8: New Knowledge Evolves by Design in a Strategic Competitory Evolution of Creative Thought

1.8 Design-Based White Space Strategy

You never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete.

R. Buckminster Fuller

New knowledge creation is evolutionary (see Figure 1-8) and—Fuller may even argue at times—revolutionary, as successful new knowledge obsoletes the existing knowledge of a paradigm. Once validated by the stakeholder's choice, the new product knowledge establishes a new level of performance, essentially raising the bar strategically for the next new knowledge evolution or new product contribution. Seeking personal differentiation in my consulting design and development business, I focused on creating advantaged new knowledge. This business strategy required bringing focus to new competitive spaces, or what I have called white spaces, for this creation quest. I use the term “white space design” to describe the strategic design practice for creating new competitive advantage.

White space designs that create value beyond form and function are necessary marketplace differentiators in crowded competitive markets. Additionally, when designing beyond form and function, they can collectively create powerful complementary advantages. This is particularly true in design challenges where the product has evolved competitively; existing products have very strong user-endowed product relationships. For example, for consumer brands or markets where the evolution of stakeholder expectations and preferences have set the bar high, new pioneering designs need distinct and multiple competitive advantages in order to break through and compete against established user product/artefact endowed relationships often found in mature marketplaces.

My personal phenomenology of design practice exemplifies the tacit nature of practice in strategically seeking white spaces in pursuit of new value, by combining differentiated and novel product experiences with novel form and function. As the next step, I have translated my evolved tacit knowledge of creating competitive advantage in practice into an academically rigorous, evidence-based epistemology of the process. The evolved learning of this reflective practice has created an ontological collection of lessons or heuristics derived from the laboratory of real-market experiences described in detail in Chapter 4.

1.9 Technically Rational Roadmaps Versus Design Inquiry Heuristics

Design practice is unique; it is not a formulaic stepwise rational process as often defines an explanatory-based pursuit of new scientific knowledge. Designing new knowledge shares designerly heuristics (rules-of-thumb-based enquiry) applied to problem-finding, need-finding, and other heuristics executed with evidence-based rigour. These heuristic tools represent the method of enquiry applied strategically on a case-by-case context depending on the designer's quest for knowledge (see Figure 1-9). The proficiency of the individual in designing competitive solutions is critical.

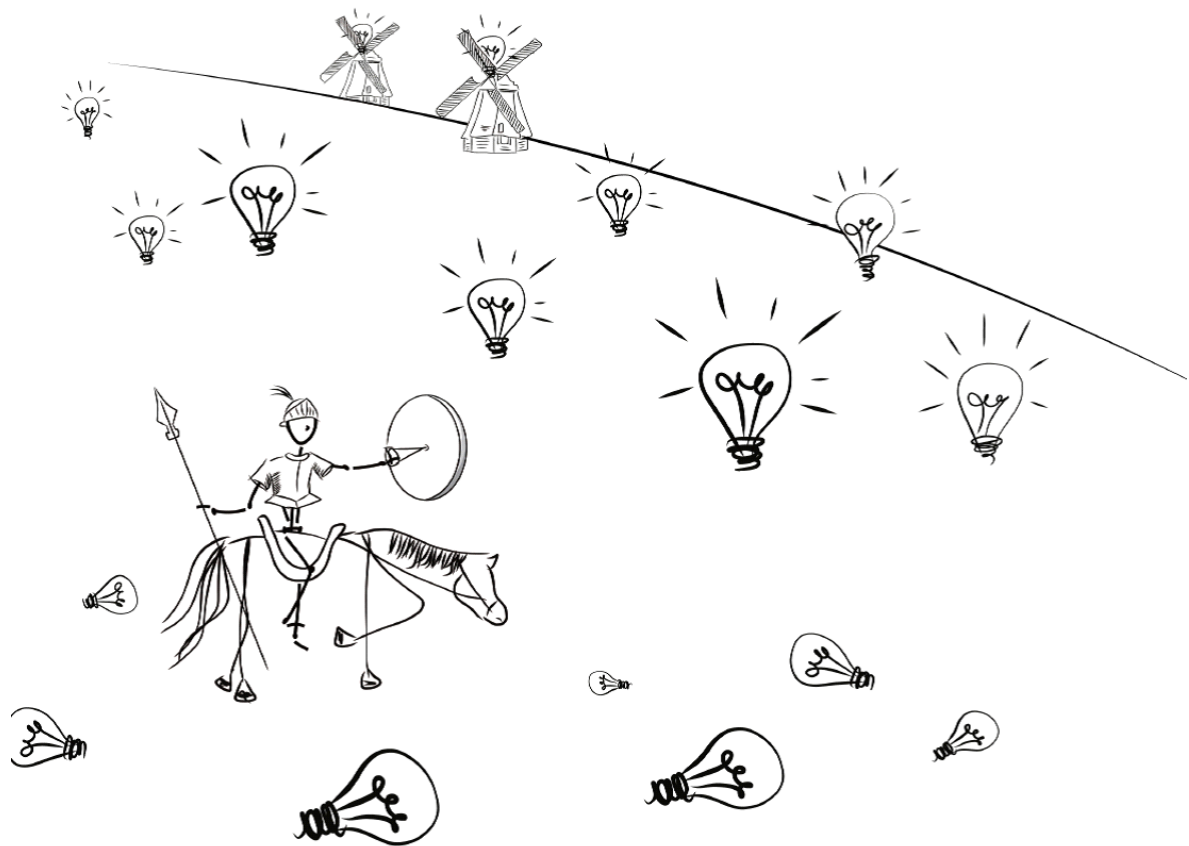


Figure 1-9 Researcher on a Design Quest for the Unexplored Contribution to New Knowledge

In his book *The Reflective Practitioner*, Schön has built a model of the cognitive interpretation of the design process to understand how practitioners when designing create new preferred situations from existing situations. Schön has developed a model of practitioner-reflective learning through a professional's ability to learn from knowing that originates from practice. I have experienced this concept of reflective-practice learning first-hand in my career by reflecting on my own phenomenology of practice, now evidenced in this academic explanatory study of a past practice.

Through reflective research and discovery, one can explicitly iterate the heuristics and explain in an academically rigorous manner the path that brought him to the new knowledge contribution space. However, I have found through this study that following systematic roadmaps will not lead to new paradigms but rather confirm existing paradigms, as found in repeated practice. New product knowledge creation alternatively relies on the designerly paradigm-changing quest by pursuing new pathways in unexplored spaces, as seen in the case histories. The nature of this explorative uncharted pathway aspect of design defines, explores, and explains the frustration that is associated with exploratory new product design practice. Rationally, only once new knowledge is created, can the previously unexplored pathway to that particular knowledge be researched and explained.

Schön and many others have offered models of the design process to explain how this creation process works. Most of these models employ interpretive understanding, referred to as “hermeneutic circles”. Although an understandable objective for teaching design, attempting to map the explicit design steps for creating new knowledge, as we can with existing knowledge practices such as physics or mathematics, has proven futile. A universally accepted systematic design process model has been allusive because the paradigm-changing nature of the design process resists systematic road mapping. This uncharted nature of the designerly form of enquiry creates a challenge in teaching as well as in academically explaining the creative design process.

Therefore, it is not an objective of this research to articulate which hermeneutic design map or model best represents the actual design practice. I have observed that each new design knowledge contribution creates its own novel step-by-step pathway. The steps to new product knowledge contribution are unique to the challenge they encounter, relying on designerly heuristic-based research methods of design enquiry to trailblaze new roadmaps for new product knowledge contribution. It was not, therefore, the intention to explore the research questions in the context of generally accepted hermeneutic models, e.g., spiral, circular, iterative loops, or even linear stage gate models. This research instead seeks to explain the new knowledge heuristics of design proficiency of enquiry (ontology) for employing this designerly process as a disciplinary practice of product design for creating competitive advantage (epistemology).

1.10 Academic Rigour Arising from Autobiographic Narrative Research

The broader research enquiry of this reflective research process may well lie beyond the research questions below. “How can this research of past practice be best achieved in an academically rigorous manner?” This research protocol presents many challenges beyond the primary research questions and raises a number of additional challenges addressed to establish the foundation for this original research quest. The unique nature of this autobiographic research and its protocol evokes the possibility that this study may be one of the first in product design, if not the first practice-led Doctoral thesis arising out of examination of the researcher’s own design practice.

This type of autobiographic narrative research, currently found in education, nursing, and the social sciences, is defined by Armour as, “[Autobiographical narrative research—or autoethnography—is where the researcher takes the dual role of both researcher and researched](#)” (Armour and Chen 2012: 238). Therefore, I have rigorously structured this research plan as an autobiographic reflection on practice, supported by quantitative case study data of three new product histories. As previously discussed, my research protocol is built with an acknowledgement and awareness of potential bias, the reliance on objective historical evidence as data sources and the mixed methods confirmation of product cases that have demonstrated competitive advantage in commercial and consumer markets.

1.11 Overall Aims and Objectives of this Doctoral Research

The explanation of how design creates new value and competitive advantage in commercial markets, at least in the U.S., has been lacking. Business leaders have embraced a design thinking new-value creation mantra for business, although from my experience, the consensus on what design thinking is or how it functions in the creation of new value has yet to be researched, analysed, and explained adequately. Having competed in markets for 35 years and pursued many commercially viable new-product challenges, I agree with the consensus that it is design that will anchor competitive advantage creation in the future, although I am concerned with the lack of understanding and explanation of how this commercial viability is designed.

The following research questions have emerged:

1. How and when do practitioners determine it is necessary to seek new knowledge (design), rather than use their existing domain knowledge in practice?
2. How and when do practitioner-designers determine the value benchmarks or stakeholder choice drivers that act as the metrics for judging competitive advantage in commercial markets?
3. How and when do practitioner-designers strategically identify and design differentiators that add value and compete for the stakeholder's choice in new product design?
4. How and when do practitioner-designers sustain the organization's competitive advantage in the marketplace?
5. Is there a potential new differentiation by design theory for explaining the how of creating competitive advantage in new product design and development?

This chapter articulates an auto-ethnographic reflective study of the design process for creating new value and competitive advantage, and the questions to be pursued in this research. This new knowledge creation quest is the designerly process of seeking, conceiving, and creating product differentiation by skilfully employing the designerly process heuristics of a proficient designer. The pursuit of this academic research requires that a review of the existing literature be undertaken to establish the existing knowledge benchmarks. Having surveyed the literature, it became apparent that the terminology in this space, and meanings of words, required a thorough organization and definition of the meaning of the terms as they related to the product design and development process of the research.

1.12 Glossary of Terms

For discussion, it became obvious that a semantic foundation was required for clear and explicit communication. This being a reflective practice of my own design, I have also recognised the need to anchor my reasoning and enhanced meanings of established terms resulting from an established reference foundation. Thus, for this study the explanations of how design creates competitive advantage remain concealed in the tacit practice cultures of multi-disciplinary practitioner-designers. These practitioners have their own vocabulary and culture, creating a complexity that underlies the challenge of trying to unpack the insights and answers.

Developing a common explanation to the questions must ultimately rely on a common definition of terms for clarity in this study. Therefore seeking a common meaning, I have defined a number of terms, some more thoroughly developed in Chapter 2, to allow for a foundational logic and argument. Thus, in an effort to assign objective meaning to terms that I heavily rely on, the following definitions provide support of the thesis argument and synthesis.

Auto-Ethnography – A form of qualitative research in which an author uses self-reflection and writing to explore his personal experience. The researcher's subjectivity is recognised, and in the research it is balanced by the qualitative objective data available to him. (Working definition adapted from Ellis)

Added Value – The successful result of new design benchmarked against an existing or previous stakeholder experience. Also defined as benefits relative to costs, not benefits alone. (Adapted from Porter)

Abductive Reasoning – A form of logical inference that goes from an observation to a theory that accounts for the observation, a form of designerly dialectic mental modelling, seeking to find the simplest and most likely explanation. (Adapted from Sober and Elliot, *Core Questions in Philosophy*, 5th edition)

Consumption Chain – Any point at which the marketplace or stakeholders interact with the product. (Adapted from MacMillan)

Choice Drivers – Value-based benchmarks that stakeholders use as metrics for judgement when choosing one product or solution over another. (Author)

Competitive Advantage – The value that a new commercial product brings by raising the customer's willingness to pay or by lowering a stakeholder's opportunity cost in a competitive market. (Adapted from Michael Porter)

Competitory – Strategically improving one's competitive position, acting in competition or rivalry. (Adapted from *Webster's New International Dictionary of the English Language* [1909, revised in 1913])

Confirmation Bias – The tendency to interpret new evidence as confirmation of one's existing beliefs or theories without objective evidence to support the claims. (Working definition <http://www.forensic-pathways.com/confirmation-bias-ethics-and-mistakes-in-forensics/>)

Customer Getting – A marketing term that describes those products, services, or business attributes created through differentiation to compete for the consumer's choices in the marketplace. (Adapted from Ted Levitt)

Design – (verb) How humans seek, conceive, and create new knowledge. (Adapted from Nonaka as organizational advantage arises from knowledge creation)

Design – (noun) 1. The new knowledge outcomes of design. 2. The process of designing based on the heuristic-based methodology of new knowledge creation by designers. (Author)

Design Engineering – The design process engineers use to solve engineering problems when existing knowledge of practice falls short and new engineering is required. (Working definition)

Design Method – A method of research and enquiry in which a problem is identified, needs are defined, and a new knowledge solution is iterated and validated using the appropriate qualitative and quantitative methodology. (Author)

Design Quest – The designerly motivational drive of humans in seeking to conceive and create new knowledge as they encounter challenges in their daily lives or attempt to create competitive advantages. (Author)

Design Science – The systematic enquiry of designerly actions, which emphasises the researching, analysing, synthesizing, and validating activities of enquiry versus process roadmaps of the design process. (Author)

Design Thinking – The popular name given to the designerly form of research and qualitative enquiry process for creating new value and advantages in competitive environments. (Author)

Designerly – Creative actions of enquiry that are the essence of the designer's process and that employ the design methods of enquiry and heuristics in the human quest to creating new knowledge by design. (Adapted from Cross)

Deweyan Enquiry – A hermeneutic process of learning that follows a sequence of asking, investigating, creating, discussing, and reflecting in learning arising from actions and experience. (Adapted from John Dewey)

Dialectic Modelling – The cognitive value-based benchmarking by designers that compares and judges existing knowledge with new propositional knowledge possibilities for sparking a synthesis. (Adapted from Hegel & C-K Theory)

Differentiation – The experience or action of arriving at a new and different embodiment compared to a pre-existing embodiment. (Adapted from Ted Levitt)

Discipline of Design – The academic branch of knowledge that incorporates expertise, people, projects, communities, challenges, studies, enquiry, and research devoted to creating paradigm-changing knowledge. (Adapted from Archer)

Engineering – An explicit knowledge practice in which practitioners generate, evaluate, and specify concepts for devices, systems, or processes whose form and function meet the stated requirements of the project. (Adapted from Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. [2005]. 'Engineering design thinking, teaching, and learning.' *Journal of Engineering Education* 94 [1], 104–120)

Engineering Design – The process engineer's practice, when seeking solutions to known requirements utilizing existing engineering knowledge best practices. (Adapted from Ertas, A. & Jones, J. [1996]. *The Engineering Design Process*. 2nd ed. New York, N.Y.)

Explicit Knowledge – 1) Knowledge that can be explained through verbal statements and descriptions. 2) Existing knowledge of a discipline's paradigm used by the stakeholders of the discipline. (Adapted from Martin Davies)

Hegelian Dialectic – An interpretive method in which the contradiction between a proposition (thesis) and its antithesis is resolved at a higher level of truth (synthesis). (*Collins Dictionary* Working Definition)

Hindsight Bias - A phenomenon in which individuals who knows the outcome of an event judge that outcome as more likely than they would have, had they not known the outcome. (Rehm)

Implicit Knowledge – Knowledge that is not yet explicit; the tacit and unarticulated knowledge of a practitioner is implicit. (Polanyi)

Innovation – When new knowledge achieves competitively advantaged outcomes over the existing knowledge. The strength of an innovation is its ability to withstand all efforts to compete with it. (Author; adapted from Kuhn, Porter, Levitt, Miller, Kuczmarski, Verganti, Kotler)

Knowledge - The fact or condition of knowing something with familiarity gained through experience or association. (Adapted from *Merriam-Webster*)

Knowledge Paradigm - The collective, accepted stakeholder wisdom of a subject that gives rise to a proficiency in practice of that knowledge. (Adapted from Schön)

Market Viability – Solutions that meet competitive, commercially viable conditions based on social, economic, ethical, and technical needs. (Author)

Need Finding – The designerly process of identifying the often unmet needs of a paradigm's stakeholders anywhere in the consumption chain of a product experience. (Author)

Paradigm Confirming – Actions that support existing knowledge of practice. (Author)

Paradigm Changing - Actions that change an existing knowledge practice. (Author)

Philosophy of Design - The study of assumptions, foundations, and implications of designerly actions originating from the human quest for problem solving, or the pursuit of creating new knowledge by design. (Working definition)

Practitioner – A practicing specialist who uses the existing knowledge of practice to solve problems in an application of explicit disciplinary practice. (Author; adapted from Schön)

Practice-led - The explanatory research of studying the outcomes of practice when developing new theory. The focus of this research is to advance knowledge about practice, or to advance knowledge within practice. (adapted from Linda Candy)

Practice-based - The exploratory research of creating new outcomes through the design process. An original investigation undertaken to gain new knowledge partly by means of practice and outcomes of that practice. (Linda Candy)

Pragmatism – A philosophical approach that assesses the truth of meaning of theories or beliefs in terms of the success of their practical application. (*Oxford Dictionary*)

Problem finding - The designerly strategy of identifying, discovering, analysing, framing, and seeking the root cause of problems in the design process. (Adapted from Deming)

Prior art – A term that has evolved from patent law describing evidence that an invention has been previously made public. (Working definition)

Scientific Method – A method of research and discovery in which a problem is identified or an observation is made, relevant data are gathered, a hypothesis is formulated from these data, and the hypothesis is empirically tested in a quantifiable methodology. (Working definition)

Stakeholders – All influencers in a position of interest or concern that judge the validity of a new knowledge proposition when compared to the existing accepted knowledge of the paradigm. (Adapted from Atkinson)

Small Manufacturing Entity (SME) – An EU (European Union) designation for the category of micro, small, and medium-sized enterprises that employ fewer than 250 persons and that have an annual turnover not exceeding 50 million euro, and/or an annual balance sheet total not exceeding 43 million euro. (European Commission)

Tacit knowledge - Knowledge that is difficult to transfer to another person by written or verbal means; the artisan's proficiency of practice. (Adapted from Polanyi)

White space – the designation given to those new open-opportunity areas in business where a designer can focus his creative efforts toward creating new value and competitive advantage strategically by design. (Working definition)

2. Literature Review – Introduction

Design is a human activity of long standing. Its appearance in the world marks the progression of life from a proto-human to a human state. Design happens whenever a person intentionally creates something, as each of us must do multiple times daily to meet life's needs.

Raymond A. Willem, "Varieties of Design"

In this chapter, the literature review articulates the existing theoretical frameworks of the designing processes and creation of competitive advantage arising from those design processes. In support of the contribution, I will review the literature beyond the traditional management of the design process to include the cognitive dialectic modelling and business literature supporting the creation of competitive advantage in commercial markets. The literature review focuses on how design seeks, conceives, and creates new value-based competitive advantage in commercial marketplaces.

The themes of the literature review will derive from:

1. The need for a consensus of a meta etymology or definition of design that is a shared design outcome of the many design sub-disciplines in design practice.
2. How new-knowledge, value-creating opportunities emerge from designerly enquiry and creative actions across the sub-disciplines of design.
3. How these new-knowledge opportunities can strategically emanate from design when focused on differentiation-based white-space solutions.
4. How the degree of product innovation is based on the level of differentiated competitive advantage that new product design brings to the marketplace.

These themes, along with the research questions, evolved as the research process unfolded in a Grounded Theory approach. Grounded Theory is a constructivist research methodology that allows the construction of theory from the analysis of data as it arises in the research process. My goal of this review is to articulate the existing thinking of thought leaders through a literature review of these themes in the context of the research questions. This review is presented in a sequential, narrative-type format, whereby the key terms are developed and the primary themes are discussed in relation to the existing literature in a logical sequence.

2.1 The Design Quest is Part of What Makes Us Human

Revolution by design and invention is the only revolution tolerable to all men, all societies, and all political systems anywhere.

R. Buckminster Fuller, *Utopia or Oblivion: The Prospects for Humanity*

Design is an innate, human, natural drive; it can be seen in all human activities in social, political, interpersonal, and professional practice. Friedman says, “The forces that give rise to the modern mind go back over two and a half million years to the unknown moment when *homo habilis* manufactured the first tools” (Friedman 2000: 7). This design ability arguably is the behaviour that distinguishes humans from other species. Archer, among others (Friedman, Willem), have proposed that design is fundamental to the human condition. Putting forth the proposition that “tool design” in pre-human *Homo habilis* played a catalytic role in the evolution to *Homo sapiens*, Archer says that “one of the attributes” that define human beings is that they “devise and make tools, and use these tools to adapt their environments.” He also says, “Another definitive attribute of human beings is, of course, their ability to invent and use language” (Archer 1992: 7). A propositional paradigm is that this innate design spirit, cognitive reasoning, and synthesis ability of humans to naturally explore, research, analyse, and create, is what I refer to as a “design quest” (“quest” signifying—beyond “searching”—a cognitive, strategically motivated exploration).

This cognitive human design quest might explain why design is so prominently interdisciplinary, as it does not originate from an individual’s academic discipline or specialty, but their innate human nature. Willem describes the case of monkeys using sticks to pull ants from the ground as a form of tool use, but acknowledges that there is no evidence that this was innate, discovered by accident or cognitively designed behaviour the first time it was attempted. “Design occurs when the intention [to] design is present and when the action taken is derived at least in part from a creative sense rather than instinct or imitation” (Willem 1990: 45). This is an important distinction of the action. Humans have the distinct capacity to strategically advance new knowledge, what Archer (1965) calls the “creative leap,” that is in my view the most likely argument for what distinguishes humans from animals. Whilst simple use of sticks may possibly have been discovered by accident, their ongoing improvements through a cognitive design process are unlikely to be undertaken by non-humans.

I disagree with Willem's claim that design is solely about taking the action, while science was the discipline in which knowledge was created. "The goal of design is not to produce knowledge but rather to take action, to produce change in man's environment" (Willem 1990: 43). From the perspective advanced in this study, when comparing the two, both design and science (natural sciences) share the designerly quest of design actions. Whilst Willem ascribed this knowledge creation to science alone and the activity to design, I would respond that the scientist is designing, or acting as a designer-in-action, when he creates new knowledge of natural science or new knowledge of practice. Conversely, the scientist-practitioner practices science when he uses the existing knowledge of the discipline in practice.

The designer-discovery quest that I will argue is at the heart of design arises within all disciplines in proficient practice. This occurs when their domain knowledge of their practice falls short of solving the problem, yet the practitioner as designer must seek and create a novel solution. Perkins, in his book *Knowledge as Design* (1986), addresses the question "what is design?" Answering his own question, he states: "If knowledge and design are so central to the human condition, then a speculation looks tempting. The two themes might be fused, viewing knowledge itself as design" (Perkins 1986: 2). Building on the insights of previous thought leaders that I will discuss in this literature review, I am proposing a broad definition of design based on design as new knowledge creator. Whereas knowledge can emerge in different ways, I will frame design as the human-driven creation process of new knowledge rather than discovery by accident, or the acquisition of existing knowledge through pathways of learning such as observation, experience, practice, reasoning, logic, and formal instruction.

Friedman summarises some of his research addressing this topic in his paper "Creating Design Knowledge: From Research into Practice." He tackles the complex and confusing dynamic of researching the nature of design domain knowledge:

On the one hand, design is anchored in a range of trades or vocations or crafts. These have never been defined in philosophical terms because they have had no basis in the work of definition. Instead, they are rooted in unspoken assumptions anchored in the inarticulate nature of practice going back, not simply to prehistory, but rooted in our prehuman development (Friedman 2000: 9).

As Friedman has pointed out, design permeates our lives, is a basic element of our nature, and is quite possibly an essential distinction of what makes us human. He also describes how design practice is an interdisciplinary discipline, and not easily separated or distinguishable from disciplinary practice. This thesis argues a universal commonality-based meaning built on design's role in new knowledge creation across the many disciplines of practice.

2.2 The Dichotomy of Defining a Design Body of Knowledge

All truths are easy to understand once they are discovered; the point is to discover them.

Galileo Galilei, the *Second Day*

Defining design has challenged designers for the past fifty years. Fuller proffered the term “design science” in the 1960s as he attempted to articulate the systematic organised body of knowledge that comprises design for its problem solving ability. “Amongst other grand strategies for making the world work and taking care of everybody is the design science revolution of providing ever more effective tools and services with ever less, real resource investment per each unit of end performance” (Fuller 1971: 20). Fuller was looking for a design-process and knowledge explanation and definition, using the term “science” to represent the organised body of knowledge of design, not science as the study of nature's knowledge. He envisioned design as the solution for the problems and social issues in society, not viewing design as a form of natural science. Fuller embraced a far-reaching purpose for design, which I believe is an element of the human design quest embodied in a social value, creating a designed objective for improving the human condition.

In *The Sciences of the Artificial*, Simon contemplated the question of new knowledge creation, offering an insightful observation about design and its role in knowledge creation. “Design, on the other hand, is concerned with how things ought to be, with devising artifacts to attain goals. We might question whether the forms of reasoning that are appropriate to natural science are suitable also for design” (Simon 1996: 114–15). Simon's view is revealing, as it suggests that new knowledge “ought to be”, also bringing attention to the difference between the designer's role in creating and exploring versus explaining existing knowledge. Archer (1979) supports this new-knowledge contribution element as a component of design by defining design as “The capacity for envisioning a non-present reality, analysing and modelling it externally,

[it] is the third great defining characteristic of humankind, along with toolmaking and language use” (Archer 1992: 8). The transition from an existing state of knowledge to a new state of knowledge is at the heart of this designerly process.

In addition to alluding to design’s creative actions, Archer also supports the argument that design arises as a unique human capacity to envision. Friedman also puts forth the view that design is more than the results of the design process, alluding to the action of design, stating, “The outcome of the design process may be a product or a service, it may be an artifact or a structure, but the outcome of the design process is not ‘design’” (Friedman 2000: 9). Many thought leaders agree on this distinction of design’s unique nature, as a human activity for seeking, creating and envisioning what can be (Archer, Fuller, Cross, Simon, Friedman).

Perkins characterised design from two perspectives: active and passive knowledge. Active knowledge springs from action, and passive from the accumulated knowledge of past actions. Perkins (1986) argues that in some way all knowledge is design like, when the information connects to a purpose. “Possibly knowledge as information is the right way to think about academic knowledge. On the other hand, perhaps academic knowledge can be thought of as design ... In academic settings, we often treat knowledge as data devoid of purpose, rather than as design laden with purpose” (Perkins 1986: 3). Perkins makes some good points, particularly about existing knowledge as the academic form and new knowledge as distinct from that. Building on this duality of knowledge states, I see the dialectic of knowledge synthesis arising out of the interplay of existing knowledge and new knowledge conditions.

Östman (2005) argues that design theory and the knowledge of design constitute a philosophical discipline engrained in our daily lives and emerging from a shared stock of knowledge. Commenting on the complexity of defining what is design and the difficulty of explaining and articulating design knowledge, Östman reports, “One problem is that design practice, design research, design theory, design knowledge and design research methods seem identical or show that much similarities that the differences are difficult to distinguish” (Östman 2005: 2). This lack of a consensus on what design actually is, defines the challenge for establishing a common meaning for design among all the disciplines that practice it, and thus necessitates the research to define a common meaning for design to move forward.

2.3 Etymology of Design – Seeking a Common Meaning

Design when used as a noun represents the artefact or outcome of the process and when used as a verb represents the actions and activities for creating those outcomes. Although these meanings diverge throughout the many disciplinary interpretations of design, definitions that embrace one discipline is over another discipline's meaning undermine a consensus -based universal meaning. "The word *design* is used by many professions (artists, architects, all disciplines of engineering) and is claimed by each" (Buede 2009: 4). Pursuing a common meaning for an important term is not unique to design; as Stubbs describes in his book *Words and Phrases: Corpus Studies of Lexical Semantics*, this evolution of meaning is more fluid and dynamic than is comfortably reliable for the certainty required for academic rigour. "Words do not have fixed meanings which are recorded, once and for all, in dictionaries. They acquire, or change, meaning according to the social and linguistic contexts in which they are used. Understanding language in use depends on a balance between inference and convention" (Stubbs 2001: 13). As can be seen from Stubbs, we know that the meaning of words differs even within a common culture or discipline. Words also gain new meaning and lose meaning as they evolve in the social, political, and cultural discourse of life. Whilst seeking a consensus-meaning common to all disciplines was challenging, it is also necessary for this study.

Design is an action-based human quest, unique and present in all practitioners, and not the outcome artefacts of the design activity. Archer, Cross, and Friedman also emphasised that design (or designerly actions) is indeed the creative activity rather than the outcome of that creative activity, stating, "The habit of calling a finished product a design is convenient but wrong" (Archer 1979:1). Thus, in pursuit of a common meaning, the question is "what connects design's actions to all the various professions and disciplines that use design practice?" I will pursue this consensus meaning by seeking to build a shared, or "meta," universal connector "meaning" definition that can be shared by all disciplines.

In my literature review, I discovered that researchers Ralph and Wand have tackled the exhaustive task of compiling existing specialty definitions of design in their paper "A Proposal for a Formal Definition of the Design Concept" (2009). They summarise their work in seeking a common definition:

The work we describe here is motivated by the observation that a clear, precise and generally accepted definition of the concept of design can provide benefits for research, practice and education. Our literature study indicated that such a definition was not available. We therefore undertook to propose a definition of the design concept. The definition views the design activity as a *process*, executed by an *agent*, for the purpose of generating a *specification* of an *object* based on: the *environment* in which the object will exist, the *goals* ascribed to the object, the desired structural and behavioural properties of the object (*requirements*), a given set of component types (*primitives*), and *constraints* that limit the acceptable solutions. (Ralph and Wand 2009: 125)

This relatively recent research of the literature identifies and analyses thirty-three popular definitions of design dividing the definitions into two categories: “plans for an object” and “planning or devising as a process” (Ralph and Wand 2009: 129).

Summarizing a very long definition from this study, they state that design is a: “process, executed by an agent, for the purpose of generating a specification of an object, based on the environment in which the object will exist, the goals ascribed to the object, the desired structural and behavioural properties of the object (requirements), a given set of component types (primitives), and constraints that limit the acceptable solutions” (Ralph and Wand 2009). This definition falls short of achieving a common meaning and is complex and almost tortuous to follow. It lacks a universal-design cohesiveness that I believe is required in a clear and all-encompassing definition of design as a verb, and one that focuses on an action-based process.

2.4 The Knowledge Gap in Practice

The engineering scientist and the natural scientist travel the same road but sometimes in opposite directions. The engineer goes from the abstract to the concrete; other scientists from the concrete to the abstract.

Gordon L. Glegg, *Making and Interpreting Mechanical Drawings*

When researching this literature review I chose to pursue a universal meaning-connection for defining design across the diverse disciplines that use it, such as art, music, and mathematics. Strategically I elected to reframe the challenge, choosing to focus on the state of mind of the practitioner in practice. Mentally exploring this new perspective, I found that the answer revealed itself to me when reflecting on my own

design practice. I questioned myself: in my product development work, when was I practicing engineering and when was I designing? My answer was right in front of me; I was practicing when I called upon conventional and proven disciplinary knowledge to complete the work, and designing when challenged to seek new knowledge where the existing knowledge of practice did not suffice. Further analysis revealed to me that in past product design practice, my design proficiency appeared as action in practice when a knowledge gap revealed itself in my practice, lacking an existing solution.

This reframed perspective builds on Schön's definition of a practitioner, "[A professional practitioner is a specialist who encounters certain types of situations again and again](#)" (Schön 1983: 60). This study builds on Schön's definition of practitioner, additionally seeking to distinguish the practice activities from design activities of practitioners as the common connector for design across all disciplines. Practice activities are defined as the use and repetition of existing knowledge of professional practice, and the design activity as the designerly discipline the practitioner must employ to solve problems when the existing knowledge falls short in practice, revealing the knowledge gap at hand. Practitioner-designer relationship is defined in the reframed sense, based on the nature of the activity of the same practitioner in action, not the body of knowledge or designerly actions of the discipline.

Addressing this knowledge gap perspective from a design as knowledge theme, Perkins comments: "[Treating knowledge as design treats it as active, to be used, rather than passive, to be stored](#)" (Perkins 1986: 18). I find Perkins's association of knowledge as a two-state active and passive interesting and relative, but it falls short of the whole picture for how it could be a common connector for defining design. Regarding passive knowledge, Perkins says, "[I construe knowledge broadly, including facts, concepts, principles, skills, and their intelligent, insightful, and sensitive use](#)" (Perkins 1986: xiii). Perkins defines design as the active knowledge shaping of objects to a purpose, which centres on the critical thinking and creativity distinguishing active from passive knowledge, which he says "[does little but await the final exam](#)" (Perkins 1986: xiii). Thus, a synthesis of this research is that design is the process of creating this active new knowledge, by focusing on the practitioner knowledge gap where passive (existing) knowledge of a discipline falls short in practice.

Perkins has also importantly addressed the design activities of problem-finding as well as solving, building on the past work of [Getzels and Csikszentmihalyi \(1976\)](#).

Perkins emphasises that often, new knowledge of the problem is necessary in the early stages of creative action: “Creativity has often been viewed as a matter of insightful problem solving, but these researchers emphasize that there is something wrongheaded about this. Significant creative achievement often involves not just finding a solution, but recognizing a problem not recognized before, or defining a problem in a new way” (Perkins 1986: 120). I support this perspective, believing that there is quite often a knowledge gap surrounding the problem definition space as well as the solution spaces (Willem, Cross, Schön, and Perkins). Practitioners are active and creative problem finders and solvers, although for a common definition I would specifically articulate that they morph into designers when called upon as the knowledge gaps appear in practice.

2.5 Design Certainty – Creating New Competitory Knowledge

A designer is an emerging synthesis of artist, inventor, mechanic, objective economist and evolutionary strategist.

R. Buckminster Fuller

Philosophers have long sought to understand the epistemology of knowledge, the theory of knowledge acquisition and dissemination, and—I will add for this literature review—new-knowledge creation. Knowledge is powerful, and the acquisition and synthesis of new knowledge are sources of competitive power in commercial practice. Strategic knowledge creation has the potential to create immense competitive advantages socially, politically, and economically in society. “In an economy”, says Ikujiro Nonaka, a leading researcher in the role of knowledge and how it creates an advantage in business, “where the only certainty is uncertainty, the one sure source of lasting competitive advantage is knowledge” (Nonaka 1991: 96). Building on Nonaka, in business, as in other competitive endeavours, new knowledge creation through the design of strategic competitory advantages is the crucial precondition for synthesizing and realizing competitive advantage in commercial marketplaces.

Dewey, in his book *The Quest for Certainty* (1929), addresses the creation of knowledge, emphasizing an evidence-based foundation. Dewey holds that the rationalism of the original philosophers, often based on observation of the natural world, cannot serve today’s world because today we have modern technology and new knowledge that requires a different evidence-based reasoning (empiricism). In his book *Human Conduct and Nature*, Dewey further comments, “Man is not logical

and his intellectual history is a record of mental reserves and compromises. He hangs on to what he can in his old beliefs even when he is compelled to surrender their logical basis” (Dewey 1922: 224). Dewey advocated an evidence-based empiricism to deal with the mental compromises and often belief-based human reasoning that still comprise a large part of human behaviour today. I find that this same evidence-based thinking is the rigour of the qualitative design process, and our vulnerability as an academic discipline when design, as new knowledge seeking is not evidence based.

Upon reflection, from a practitioner’s perspective, I find Dewey’s evidence-based certainty to be a basis of a designerly form of enquiry. Östmon, in his paper “Design Theory is a Philosophical Discipline” (2005), stated that Dewey’s philosophy was the most favourable philosophical perspective for design because of his reasoning. Applying Dewey’s logic based on evidence, designers have at their disposal all forms of reasoning, empirical, rational as well as intuitive forms of qualitative observation. This evidence-based enquiry of Dewey for seeking new knowledge allows designers access to both qualitative and quantitative methods of knowledge creation with certainty. Where an engineering practitioner will often focus on the scientific methods in practice, the same engineer will also need to embrace an evidence-based, qualitative methodology when designing.

Deweyan Enquiry has arisen in education pedagogy as a mainstream process, employing qualitative methods as well as the quantitative experimental model of science in quest of new insights arising from practice. Dewey defined enquiry as, “the controlled or directed transformation of an indeterminate situation into one that is so determinate in its constituent distinctions and relations as to convert the elements of the original situation into a unified whole” (Dewey 1938: 104–5). Dewey has conceptually described the meaning of design as articulated by many thought leaders, highlighting the transformation of an indeterminate situation – one that lacks certainty – into a determinate one – a situation of greater certainty. Dewey has contributed significantly to our modern understanding of knowledge, believing that we, as knowledge seekers, are in a continual quest for certainty arising from prior knowledge states to create new knowledge. “For knowledge to be certain [it] must relate to that which has antecedent existence or essential being” (Dewey 1929: 25). Dewey is describing here the new knowledge arising from the existing knowledge state. When seeking new knowledge, designers must first establish the existing knowledge state

as a basis for seeking, conceiving, and strategically creating new knowledge through design.

2.6 Evidence Based Ontology and Epistemology of Design

Creativity is a dynamic capability to manage problems and situations and generate solutions that matches the expectations. It presupposes suitable repertoires and the application of Dewey's controlled enquiry.

Lief E. Östman, "Design Theory is a Philosophical Discipline"

From an epistemological point of view, design has been described as activity, planning, and as epistemology Mahdjoubi [2003]. In his study, Mahdjoubi describes the existing evidence dichotomy of design epistemology versus scientific epistemology:

Apparently one can envision design epistemology as a method for expression and change (manipulation) compared with science, which is based on analysis and investigation. In other words, analytic research is the main method of science, and design is the main method of art, technology change and strategy. Science is aimed at searching for "truth"; design, however, is a method for change, expression and implementation. (Mahdjoubi 2003: 3)

Mahdjoubi further supports previous positions that the activity of design does emerge from the methodology of creating change. Building on this perspective, I would argue that the evidence of new knowledge creation is the epistemology of design, which itself arises from the ontology or worldview of design as the process of designerly evidence-based enquiry and actions of practice. Thus, this ontology and epistemology of design surfaces in practice when the existing knowledge falls short and a knowledge gap is created.

Design relies on the empiricism of systematic Deweyan enquiry for rigour and certainty by building on the various mixed methods ontology of creating change, and science relies on the rigour of the scientific method. For this study I argue that design often relies on the qualitative methods of designerly enquiry and often seeks quantitative-analysis methods of enquiry to validate those new knowledge propositions created by design, in a uniquely designerly interplay of methodologies.

2.7 Cognitive Dual Processing - Designerly Approach to Problems

Cognitive modelling exists in many contexts, but for this study, the focus of design-based cognitive modelling will be on the knowledge creation process. In 1984, Tovey introduced a dual processing model of how designers use both hemispheres of the brain. Tovey explained that designers use both the right (visio-spatial and holistic, today often referred to as expressive) and left (verbal and analytical, today often referred to as analytical) hemispheres of the brain to solve design problems in a dual processing model: “The dual processing model of the design process assumes that both halves of the brain will be working at the design problem simultaneously” (Tovey 1984: 226). The bilateral functioning of the two parts of the brain, in which they have a complimentary conversation with each other, controls the thinking in a symbiotic process where the appropriate side dominates the appropriate thinking as necessary to solve the problem. The process includes an incubation period of inactivity in which the designer’s cognitive processing reconciles the ideas, attempting to optimise the solution. This bilateral functioning model evolved into a concept of design as a whole-brain thinking type of model. This incubation is similar to Schön’s reflection on synthesis.

At my own institution, Northwestern University School of Engineering, the bilateral thinking approach is combined with human-centred design into a foundational concept for creative problem solving for practice. The education of engineers here begins with a two-class sequence based on a human-centred enquiry approach employing bilateral thinking, or a “Whole Brained Engineering” education model. This curriculum augments the traditional engineering education pedagogy with the early introduction of designerly forms of enquiry and design practice in a human-centred design methodology.

2.8 Creative Synthesis – a Dialectic Whole Brained Designerly Process

How humans rationally model and mentally construct new concepts versus existing knowledge practices through cognition is at the core of this strategic application of creativity. In discussing the relationship of creativity and dialectic in directed creativity, Paletz, Bogue, Miron-Spektor, and Spencer-Rodgers surmise that creativity is a multi-dimensional discovery process that exhibits novelty and appropriateness. “Creativity is also comprised of many subprocesses and stages, such as preparation, problem-finding and problem structuring, insight, recombination,

analogy, mental stimulation, and evaluation” (Paletz et al. 2015: 4). I agree with Paletz, and I expand on this perspective of creativity, arguing that it is an essential aspect of how designers seek new value and potential competitive advantage. In practice, product design is creativity used strategically by new product designers as they seek and create commercial competitive advantages.

One of the common theories on the origin of purposeful or strategic creative knowledge creation employs the cognitive dialectic process. Popper describes the process in relation to the scientific method as the trial and error developed consciously by the scientist as he seeks to conceive solutions to a problem. Popper explains:

Dialectic is a theory which maintains that something—for instance, human thought—develops in a way characterised by the so-called dialectic triad: thesis, anti-thesis, synthesis. First, some idea or theory or movement is given, which may be called “thesis” ... [The] opposing idea or movement is called “anti-thesis” because it is directed against the first, the thesis. The struggle between the thesis and the anti-thesis goes on until some solution develops which will, in a certain sense, go beyond both thesis and anti-thesis ... This solution, which is the third step, is called “synthesis.” (Popper 1940: 404)

Popper, a philosopher of science, describes this dialectic process as the beginning process of how a scientist pursues the scientific method on his way to a hypothesis (see Figure 2-1). The above theory originated in the late 1700s with Hegel, a German philosopher, and is named the Hegelian Dialectic.

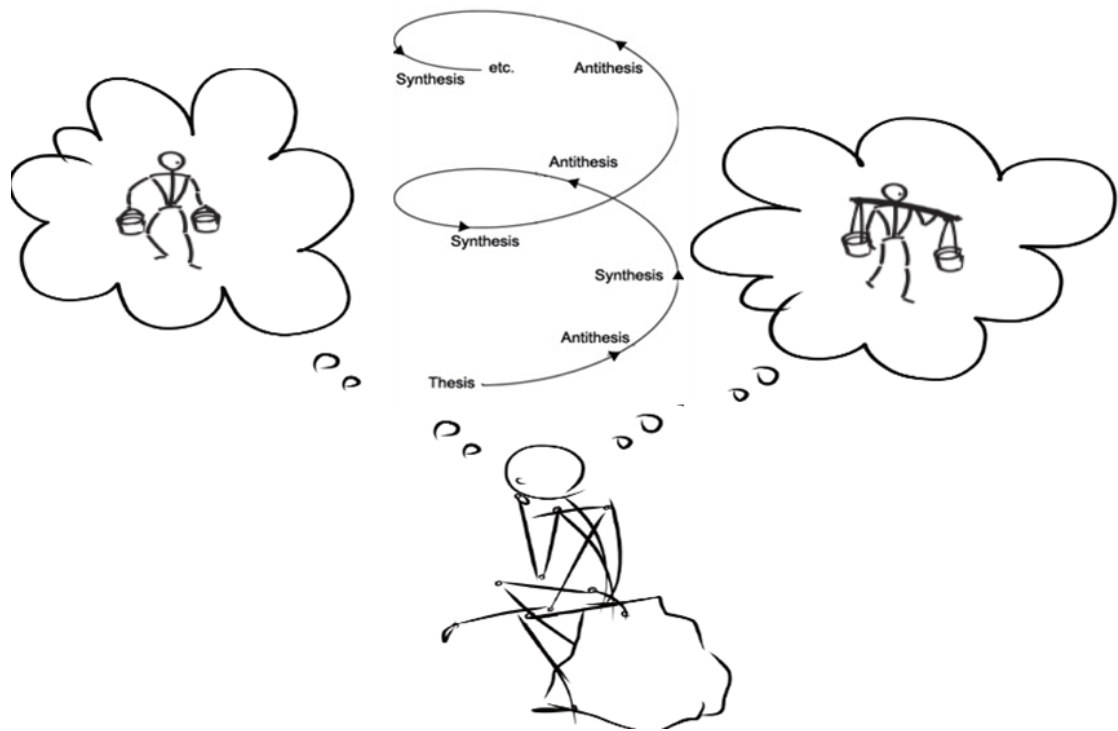


Figure 2-1: Hegelian Dialectic Modelling of a Designer Strategic Creative Thought Process

This dialectic reasoning is in essence the strategic design process of creative mental modelling. Popper is describing the often-qualitative methodology of enquiry that occurs prior to the traditional and more established scientific enquiry of the scientific method of designing a hypothesis to test. This method is relied on extensively to explain human reasoning and is acknowledged by scholars such as Dewey as the cognitive reasoning process. This process of cognition through dialectic synthesis acts as the operative process of perception and learning in the strategic creation of new knowledge. Although not a focus of this study, the process leading up to a hypothesis in the scientific method shares many of the knowledge seeking characteristics of design. A question for future study would be, is this designerly method the same as the process for getting to a hypothesis in the scientific method?

2.9 Application of the Dialect Modelling to New Product Problem Solving

A recent theory named C-K Theory (Concept-Knowledge Theory) resulting from the research of engineering practice and knowledge creation was proposed by French professor Hatchuel and his colleague Weil in 2003 (see Figure 2-2). This theory incorporates the Hegelian Dialectic synthesis into a new C-K model (C is concept and K is knowledge). The model represents the combination of the dialectic between the two states of thought of how engineers solve design problems. “Design projects aim to transform undecidable propositions into true propositions in K ...

During the design process C and K are expanded jointly through the action of *design operators*” (Hatchuel and Weil 2009: 182). The C (concept state of potential new knowledge) would appear to be the idea stage, and the K (knowledge state of existing knowledge) would align with what is known to be true at that time. The C-K and the Hegelian models share the two-state reasoning dynamic (thesis – antithesis) I would suggest that the disjunction – conjunction aspects of the C-K model align closely with the synthesis stage described by Hegel in the dialectic process.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 2-2: C-K Theory Model (Hatchuel 2008: 182)

According to the C-K Theory, a concept, defined as a proposition or idea that is neither true nor false, can arise from technical problems or market opportunities. Knowledge is defined as a collection of propositions that we know to be true or false by logical construction and validation. New-knowledge contributions are those concepts logically created and validated for the first time. “The combination of these four operators is a unique feature of Design. They capture all known design properties including creative processes and explain seemingly ‘chaotic’ evolutions of real practical design work” (Hatchuel and Weil 2009: 182). In practice, the dialectic creative thought of the C-K Model is equivalent to the iterative looping or point-counterpoint of thought synthesis in the Hegelian Dialectic.

Dewey also opined on the dialectic model in his book *A Quest for Certainty* (1929). He articulated that knowledge stems from actions and experiences and that knowing occurs upon reflection of those situations, a similar view to the one that Schön builds on in his Reflective Practice theory. Dewey describes a problem-focused process of enquiry as the object to arrive at new knowledge: “The risky character that pervades a situation as a whole is translated into an object of enquiry that locates what the trouble is, and hence facilitates projection of methods and means of dealing with it” (Dewey 1929: 213). This thesis argues that the designerly form of enquiry at the heart of the designer’s methodology is a combination of this systematic Deweyan Enquiry and Hegelian Dialectic. Dewey provides the model of evidence-based research ontology, and Hegel provides the model of how designers strategically synthesise the new knowledge states. New knowledge solutions are the results, systematic synthesis of strategic-designerly form of enquiry in situations where existing knowledge falls short.

2.10 A Common Meaning and Definition of Design

Form follows function—that has been misunderstood. Form and function should be one, joined in a spiritual union.

Frank Lloyd Wright

For seeking a common meaning of design, Herbert Simon's famous definition has provided us with a strong starting point. Simon observed, “Everyone designs who devises courses of action aimed at changing existing situations into preferred ones. The intellectual activity that produces material artifacts is no different fundamentally from the one that prescribes remedies for a sick patient or the one that devises a new sales plan for a company or a social welfare policy for a state” (Simon 1996: 111). This widely quoted definition expresses the purpose of changing an existing situation or existing knowledge into a “preferred situation” or preferred new knowledge state. Beyond that, Simon has framed a universal nature of design, meaning one that is universally applicable to all disciplines. Archer also states; “Design is described as ‘intentional’ to distinguish it from serendipity, or discovery by chance, and to place it in the social and commercial world, where practitioners are obliged to make judgements on difficult and complex issues” (Archer 1992: 9). I would characterise Archer’s use of intentionality as the strategic use of design and an important focus of the designer who strategically seeks new knowledge in practice.

In researching a common meaning of design amongst the many existing definitions of design, and building on the previously discussed points, I have arrived at this definition of design:

Design is how humans seek, conceive, and create new knowledge.

The above definition of design proposes a meaning of design that interconnects designerly enquiry and practice across all disciplines when their existing knowledge of their practice falls short and a knowledge gap appears.

- Design as a uniquely human quest for new knowledge.
- Design as a strategic research-based seeking of new knowledge.
- Design as a cognitive dialectic analysis of conceiving new knowledge.
- Design as the evidence-based synthesis of creating new knowledge.
- Design as the mixed method methodological enquiry of evidence-based rigour.

This definition provides a simple and universal meaning of design that supports further ontology or heuristic development of “how” designers create new knowledge by design.

2.11 Design Thinking – Designerly Creative Enquiry in Practice

We can't solve problems by using the same kind of thinking we used when we created them.

Albert Einstein

Having recently achieved newfound popularity in the media, business thinkers have embraced design's ability to strategically address problems and create new knowledge solutions beyond the traditional role of designers in business. Few outside the design community in Europe are aware of the history of Design Thinking that started with L. Bruce Archer 50 years ago and that Dorst described as “an exciting new paradigm for dealing with problems in sectors as far afield as IT, Business, Education and Medicine” (Dorst 2010: 131). Design thinking is now a mainstream business strategy, built on enquiry, having evolved beyond the early design researchers' emergent description of how designers do their work (Archer, Cross, Friedman, Tovey). The greater business community is now embracing this designerly form of enquiry as a strategic process of not only problem solving but also new value creation leveraging design's new knowledge-conceiving ability to create competitive advantages in commercial business domains.

Practitioners in all disciplines can act as design thinkers by employing designerly enquiry in their practice when the existing knowledge of their disciplines falls short of solving the problem. The term “design thinking” is first attributed to Archer, who, in his 1965 article *Systematic Method for Designers*, writes, “Ways have had to be found to incorporate knowledge of ergonomics, cybernetics, marketing, and management science into design thinking”. This precursor vision of design thinking also describes the discipline of design as “not merely a craft-based skill but should be considered a knowledge-based discipline in its own right, with rigorous methodology and research principles incorporated into the design process” (Archer 1965). I could not agree more; his insights and citations throughout the design literature have made an immense impact on the design community. Archer specifically refers to the rigorous methodology that is necessary for achieving the desired new knowledge outcomes, something that I believe has been lost in today’s euphoria over the Design Thinking process.

The question of what is design thinking is also addressed by Don Norman in a pair of essays (2010 and 2013) on the design site *Core 77*. Norman’s point in his first essay (2010) is that design thinking, although now currently popular, has been practiced by innovators for years. In a follow-up response to his first essay, Norman (2013) affirms that design thinking is an important form of enquiry for all disciplines as part of a creative problem management process, and he makes the distinction that whilst it is available to all practitioners, it is part of the design practitioner’s role to teach the process. “But the difference is that in design, there is an attempt to teach it as a systematic, practice-defining method of creative innovation” (Norman 2013). Norman is an advocate of the designer’s role in teaching the rigour over rhetoric of the process. I believe that it is precisely the role of professional designers to not only practice in their area of specialty, but also teach and lead the design process of designerly enquiry as a systematic, rigorous, and evidence-based research methodology.

2.12 Business Seeks Design-Based Competitive Advantages

A product is not a product unless it sells. Otherwise it is merely a museum piece.

Attributed to Theodore Levitt

Liedtka, a marketing strategist and professor of business administration, published a comprehensive analysis of design thinking from a business perspective

in her article “Design Thinking: What it is and Why it Works” (Liedtka 2013). She notes the marked increase in design thinking across many disciplines in the past five years. “While significant scholarly work has appeared in design-focused academic journals like *Design Issues*, the attention accorded to ‘design thinking’ as a problem-solving approach within top-tier academic management publications has been scant. Though anecdotal reports are plentiful, systematic assessment of design thinking and its utility as problem-solving approach is limited” (Liedtka 2013: 2). Liedtka’s thesis, and the focus of her paper, argues that although design thinking, as popularised in the business press and marketplaces for consultancies, has yet to become the focal point of academic research in business management.

Nevertheless, this has not prohibited design thinking from contributing to business discussion. Indeed, this new focus attracted academic attention from several prominent thought leaders, including Roger Martin in his 2009 book, *The Design of Business: Why Design Thinking is the Next Competitive Advantage* (Martin 2009). Liedtka, a collaborator of Martin’s, says he “has gained a wide management audience with his argument for the importance of integrative thinking ... as critical to long-term business success” (Liedtka 2013: 10). It does not appear that the popularity of design thinking in business will end soon. Competition drives the business community; survival dictates that they will always seek new opportunities to create value and competitive advantage, which, as argued in this thesis, is a design process of enquiry.

Practitioners in business acting as designers are the value creators of these sought-after commercial competitive advantages in business. Tim Brown, CEO of IDEO, has elevated this business design quest to an even higher level for those seeking a change in business thinking. “Really, what we're doing as designers is, ultimately, and inevitably, designing the business of the companies that we're working for ... Whether you like it or not, the more innovative you try to be, the more you are going to affect the business and the business model” (Brown, Rotman 2005). I agree with Brown that designers are in a unique position to influence the business beyond the traditional design of the product.

Practitioner-designers in business occupy a unique position early in the product development cycle to create new product value as well as value in the total experience with the product (see Figure 2-3). The expansion of the traditional form and function perspective of product design into the design-based differentiation and

value-creating strategies in business occurs throughout the design experience from concept to creation of a product. As Tim Brown describes, designers in business are ultimately designing the business of the companies we are working for; it is impossible to separate the design of the product from the design of the business in today's competitive market spaces. This expansion of the design process into traditional business areas provides opportunities to integrate many more value creators into the design process. As modelled below, the need to move water for irrigation can evolve into a design of a business to sell water to other farmers.

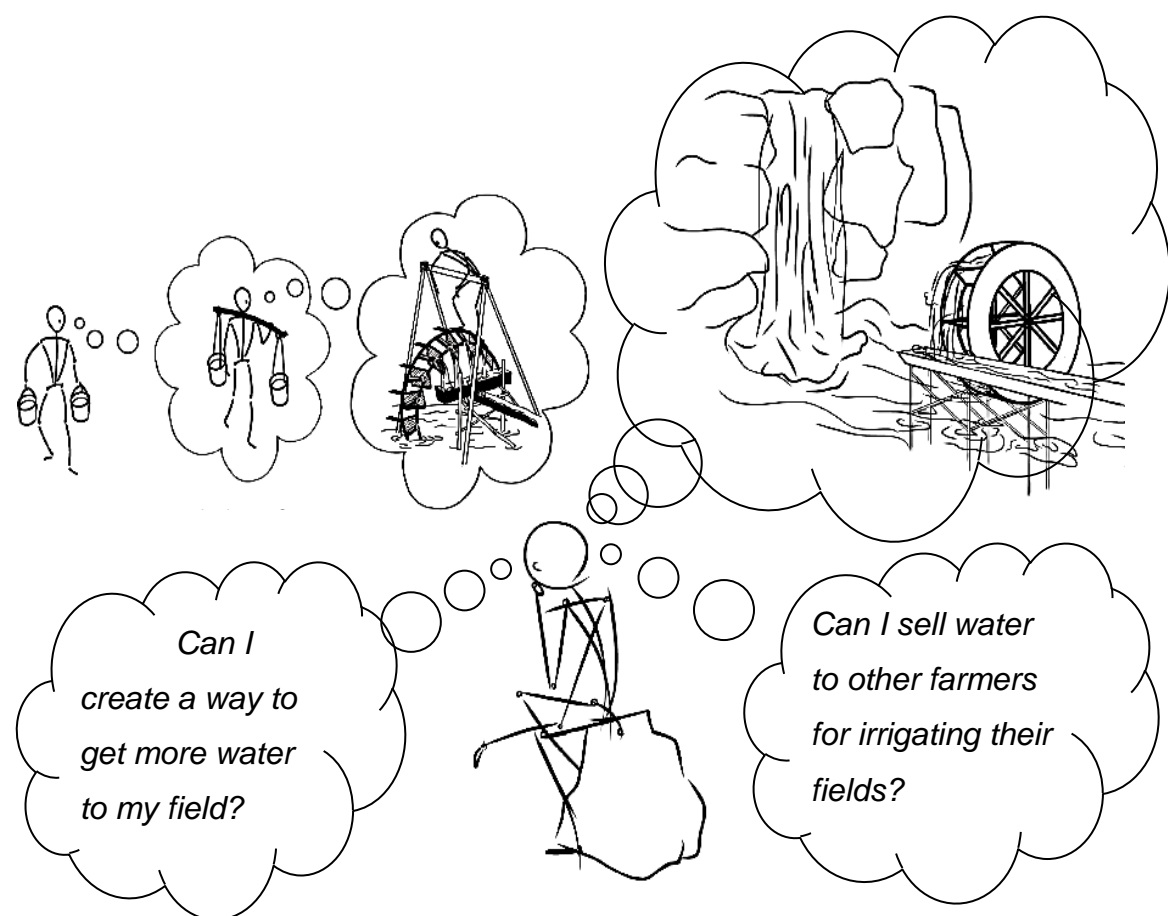


Figure 2-3 Design is How Business Strategically Creates New Opportunities

2.13 Paradigm Change - Addressing Stakeholder Endowed Beliefs

All men can see the tactics whereby I conquer, but what none can see is the strategy out of which victory is evolved.

Sun Tzu, *Art of War*

Kuhn has articulated the phenomena of paradigm change, arguing that these paradigm behavioural shifts do not happen quickly. Stakeholders of a paradigm hold steadfastly to their endowed beliefs. In his book *The Structure of Scientific*

Revolutions, Kuhn refers to Max Planck, the designer of modern quantum theory, who argued that “a new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it” (qtd. in Kuhn 1970: 151). This resistance to change is not only the dynamic of science, but is seen in the marketplace as well. Product users often have endowed relationships or biases with their existing products, so new product designers must recognise this behaviour and incorporate strategies to design a new product that overcomes this endowed bias, a process Kuhn describes as a paradigm shift.

This natural resistance to change often creates an irrational dynamic for designers pursuing product change in practice in the marketplace. The stakeholders’ natural resistance to change affects how new knowledge competes with old knowledge for change in markets. “By ensuring that the paradigm will not be too easily surrendered, resistance guarantees that scientists will not be lightly distracted and that the anomalies that lead to paradigm change will penetrate existing knowledge to the core” (Kuhn 1970: 65). These endowed anomalies of change within a paradigm must be recognised, researched, and benchmarked so that the designer may conceive strategies to prevail early in the design process where the opportunity to create change and validate it with stakeholders is available.

In the context of how humans form relationships with existing product paradigms, the economic behavioural benchmarking of change and resistance to it has been studied by Ariely in his research and his book *Predictably Irrational* (2010). Ariely explains the process of change in endowed relationships. “Standard economics assumes that we are rational ... But, as the results presented in this book (and others) show, we are all far less rational in our decision making ... Our irrational behaviors are neither random nor senseless—they are systematic and predictable. We all make the same types of mistakes over and over, because of the basic wiring of our brains” (Ariely 2010: 317). Human behaviour is indeed often irrational and, as Ariely has proven, it can be predictably irrational. Designers seeking to create change must research and understand the predictably irrational choice drivers of those stakeholders they are seeking to influence by their design. This endowed behaviour that exists for the designer with both internal and external stakeholders throughout the product experience, can—when not recognised—become an unforeseen cause of failure.

2.14 Competitive Advantage Is the Driver of Business Advantage

An organization's ability to learn, and translate that learning into action rapidly, is the ultimate competitive advantage.

Jack Welch

Defining competitive advantage is necessary for clarity. In business, the meaning of competitive advantage can be found scattered throughout the literature, but it is primarily the domain of the strategic management community. However, as Sigalas and Economou note in their 2013 paper, “Although competitive advantage is perhaps the most widely used concept in strategic management and has generated a large volume of theoretical and empirical discussion, it seems that it remains poorly defined and operationalized” (Sigalas and Economou 2013: 73). This survey of the literature on competitive advantage also notes that the lack of a common definition has implications for academic research in strategic management. Thus, defining new product design based on competitive advantage is necessary, and I will rely on the research of Porter, a well-known business authority, for this (see Figure 2-4). Porter identifies five forces that make up the commercial competition dynamic through his research (Porter 2008: 80).

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 2-4: Porter Five Forces Graphic, *Harvard Business Review* 2008

In reflecting on my product design and business practice, my experience has demonstrated that the forces that create competitive advantage can emerge

anywhere in the consumption chain often beyond form and function, for example the supply chain, customer service, distribution channel, or even business model. “Competitive advantage,” says Porter in his book *Competitive Advantage: Creating and Sustaining Superior Performance*, “grows fundamentally out of the value a firm is able to create for its buyers. It may take the form of prices lower than competitors’ for equivalent benefits or the provision of unique benefits that more than offset a premium price” (Porter 1998: xxii). These attributes, Porter says, can derive from two basic areas: pursuing a low-cost strategy and, most notably, pursuing a differentiation strategy. Both strategies benefit from designerly enquiry in seeking opportunity white spaces to differentiate from the competition. These white space value-creating opportunities are unique to the competitive circumstances of each design challenge.

Differentiation, according to Porter, articulates the business process of creating competitive advantage through creating a value chain that, most importantly, develops around those differentiators that competitors cannot copy. Porter is a leading authority on competitive strategy and the business thought leader for bringing focus to commercial competitive advantages. He is also the acknowledged originator of the term “value chain” and its use in identifying the points of product contact often beyond form and function that create value and competitive advantage for businesses; I rely on Porter’s definitions of the meaning of commercial marketplace competitive advantages as the outcome of commercial new product design. Porter’s argument builds on the precept that a strategic design process of product competition strategy is the underlying nature of the designer’s role in creating commercial competitive advantage.

Summarizing the relevant Porter arguments:

- Competitive advantage occurs when an organization acquires attributes that allow it to outperform its competitors.
- The identification and ideation of value-creating differentiators that competitors cannot copy is the goal of the new-product design process.

Porter articulates four requirements for designing a product strategy to create value and advantage:

- Activities—Perform activities that are different from rivals
- Value Created—Meet different needs and/or same needs at lower cost
- Advantage—Offer sustainably higher prices and/or lower costs
- Competition—Be UNIQUE; compete on STRATEGY

Porter's Five Forces Model (see Figure 2-4) illustrates his concept of how competitive advantage is conferred in competitive markets. It is a proposition that these advantages must be strategically designed into the product during the new product design and development process, or they will not materialise in the marketplace.

Porter explains that competitive advantage means that an organization has created value for customers beyond the competition. Organizations that create that value are able to capture competitive advantage because of the positioning afforded through effective sheltering from the profit-eroding impact of the five forces of competition. In his analysis of Porter's theory, Magretta says, [“The first test of a strategy is whether your value proposition is different from your rivals. If you are trying to serve the same customers *and* meet the same needs and sell at the same relative price, then by Porter's definition, you don't have a strategy”](#) (Magretta 2012: 106). Therefore, Porter argues, an organization's value proposition is differentiation, that is creating something strategically different from its rivals, to build a value-creating strategy that achieves competitive advantage. For designers this potential competitive advantage can emerge anywhere in the value chain: the more value creators that are designed into the product or service, the greater the value-creating strategy and opportunity to capture competitive advantage in the market. It is the designerly strategy and methodological enquiry of design that seeks, conceives, and creates this differentiation.

2.15 Strategic Designerly Enquiry as the Creator of Competitive Advantage

Recognizing why the new value creation stemming from designerly enquiry functions as a central role in business strategy is not new. [Kotler](#), professor of marketing at the Kellogg School of Management at Northwestern University and an early thought leader, identified design as a necessary organizational resource in the changing marketplace. He writes, in a co-authored article in the [Journal of Business Strategy](#), that, [“One of the few hopes companies have to ‘stand out from the crowd’ is to produce superiorly designed products for their target markets”](#) (Kotler and Rath 1984: 16). As early as the late 1980s, academic and business leaders were realizing that the competitive business landscape was changing. Globalization, efficiency in shipping products great distances, and the rise of economies looking to move up the economic ladder were combining to put significant competitive pressure on existing businesses

When it comes to new products, Kotler highlights the need to bring designers into the new product design process earlier, to leverage their ability to uncover the unmet and unspoken needs of customers, “Designers are capable of producing ideas that no customers would come up with in the normal course of researching customers for ideas. And, during the concept development and testing stage, designers might propose intriguing features that deserve investigation before the final concept is chosen” (Kotler and Rath 1984: 19). Strategically this can only happen, as Kotler points out, if the design insights are developed and integrated into the project requirements early in the development process. What Kotler is alluding to is the reality that those desired opportunities are missed if they are not strategically integrated early in the design project.

Although Kotler and Rath’s advice might seem obvious to today’s business participants, when I entered the business world 35 years ago, it was quite a departure from the traditional perspective of the role of product design in the organizational hierarchy for most companies. Traditionally, design meant the industrial design of the form of the product; today, design is the overall value-creating strategy from concept to commercialization. For the purpose of this research, the definition of competitive advantage builds on the work of business thought leaders Porter, Levitt, and Kotler, whose perspectives in business strategy align with my practical experience in the marketplace. Unfortunately, the histories of strategic competitive advantage creation are difficult to research, as information on the design process is often considered confidential. Despite this lack of access to the historical data and evidence of the creation practice, we do have the publicly available data of the marketplace.

When addressing the question of “what is an innovation?” Kuczmarski and Miller, co-founders of the Chicago Innovation Awards, respond, “You must have demonstrated success in the marketplace” (Technori 2011). Kuczmarski states that patents and trademarks can be an indicator of potential advantage, but success in a competitive environment is a demonstrated competitive advantage. Vogel says, “... the key is that an innovation is a valued leap from the viewpoint of the consumers” (Vogel, Cagan, and Boatwright 2005: 24). What defines an innovation in the marketplace is elusive. Many claim an innovation is anything new, but, as we see from Kuczmarski, Miller, Vogel, Cagan, and Boatwright, innovation is more than simply being new. Economists frame innovation as the source for economic growth and opportunity, yet many new designs fail to scale or establish economic

sustainability in the marketplace. Innovation must be associated with a metric of performance beyond simply being new. Therefore the definition of innovation will be:

Innovation is when new knowledge achieves competitively advantaged outcomes over the existing knowledge.

2.16 Designing Customer-Getting Competitive Advantage

In the paradigm of competitive commercial spaces, stakeholders judge the product value based on the ability of the new product or service to compete for sales against the competition. Levitt explains “customer-getting” advantage, emphasizing that the head-to-head product competition goes beyond function-choice drivers: “In the marketplace, differentiation is everywhere. Everybody—producer, fabricator, seller, broker, agent, merchant—tries constantly to distinguish his offering from all others” (Levitt 1980: 83). Levitt describes how marketing success can seemingly spring from the differentiation of anything that the customer values in the customer-getting process. Levitt had the foresight in the early 1980s to predict many of the market changes brought by globalization of markets. Building on Levitt’s marketing insights, this exploration expands the role of differentiation as a strategic heuristic of the design process in product development and business.

Marketers traditionally were tasked with creating the differentiation strategy. In his book *The Marketing Imagination*, Levitt states: “If marketing is seminally about anything, it is about achieving customer-getting distinction by differentiating what you do and how you operate. All else is derivative of that and only that” (Levitt 1986: 128). A fundamental argument of knowing that design has created a differentiating advantage is the customer-getting ability of the design in competitive markets. Fast moving markets, rapid development processes and short product life cycles have forced the differentiation strategy much earlier into this development cycle. Companies can no longer rely on long product life cycles to tweak a product’s advantage; without strategic advantage at launch, there is a high probability of failure, as there is very often no time to restart the investment. Thus, bringing focus to the customer-getting choice drivers of the stakeholders is a key design strategy.

In his many publications, Levitt has established the theory that “there is no such thing as a commodity,” delivering a compelling argument with examples to support the premise that all products and services have the opportunity for differentiation. Whilst the offered product gets the customer, the delivered product

keeps him. Levitt contends, “in the actual world of markets, nothing is exempt from other considerations, even when price competition rages” (Levitt 1980: 84). He argues that choice drivers often simply shift to quality, delivery, and financing once price is not the differentiator. Analysing these unique relationships helps to identify opportunities for differentiation even in commodity-based, customer-product relationships. As Levitt puts it so well, “The search for meaningful distinction is a central part of the marketing effort. If marketing is seminally about anything, it is about achieving customer-getting distinction by differentiating what you do and how you operate. All else is derivative of that and only that” (Levitt 1986: 128). Competitory strategy integrated into new product design early in the development process will serve to bring focus to those design opportunities to create customer-getting advantages customers will pay for.

2.17 Design Differentiation Research into the Opportunity White Spaces

In *Design-Driven Innovation*, Verganti expresses the need for business to create new and useful value and competitive advantage through new-product design. He acknowledges the value that human-centred design has brought to the research process, but then he pushes deeper into the organizational needs to create new products that also create new meaning for users. “We call the radical innovation of meanings *design-driven innovation*, or *design push*, because it is propelled by a firm’s vision about possible breakthrough meanings and product languages that people could love” (Verganti 2013: 56). Verganti supports Levitt’s view that organizations need to rise above traditional form and function in the customer-getting process, and he emphasises the role of design in new-product development as the value creator for innovation.

In “Discovering New Points of Differentiation,” Ian C. MacMillan and Rita Gunther McGrath describe opportunities to gain insights into new value creation opportunities, beyond the traditional form and function of a new-product experience. Their strategy outlined in the article for mapping the consumption chain (see Figure 2-5) and identifying key stakeholders is an excellent method of researching and benchmarking existing product experience from all stakeholder perspective of the consumption chain. They write: “a company has the opportunity to differentiate itself at every point where it comes in contact with its customers – from the moment customers realize that they need a product or service to the time when they no longer

want it and decide to dispose of it” (MacMillan and McGrath 1997: 133). Arguing from a designerly perspective, integrating this marketing style research into the design research early in the design process can augment opportunity for value creation. Consumption Chain research has the ability to not only benchmark the steps identified in the article, designers can also analyse each step in the development process to gain insights into the internal stakeholders’ needs such as manufacturing, and suppliers as well as the external stakeholders identified in this primarily marketing focused article.

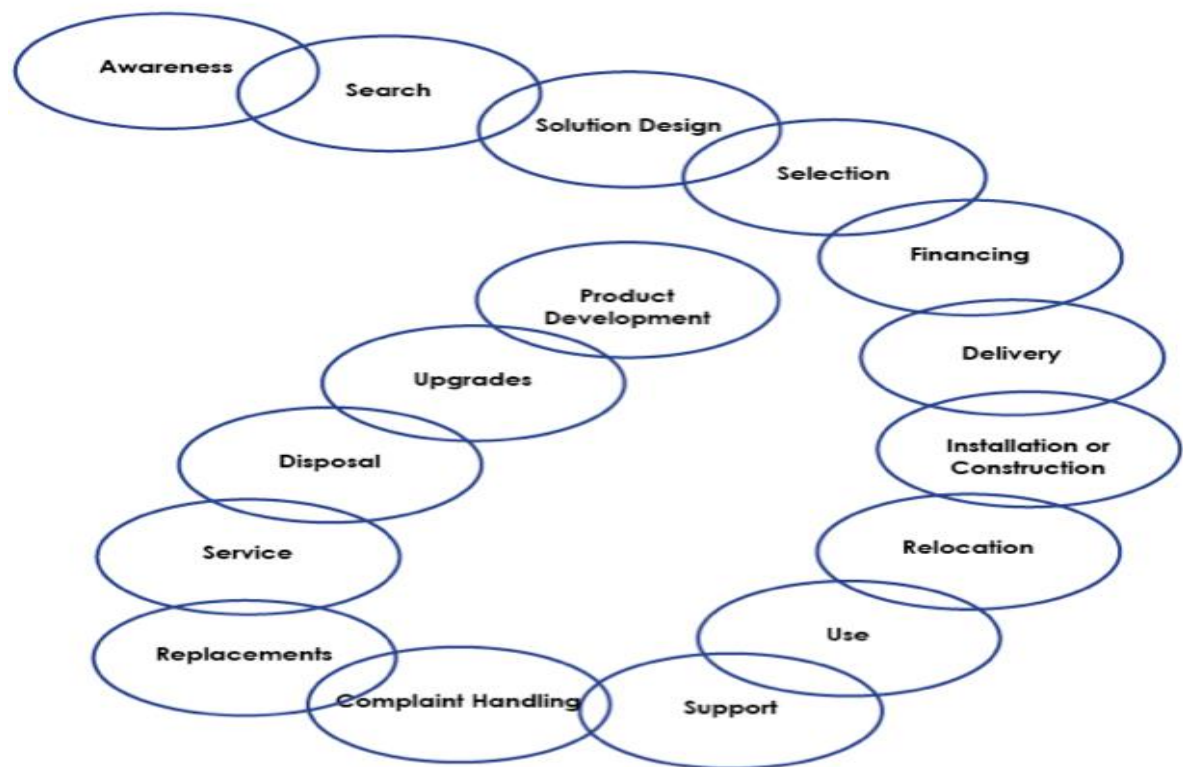


Figure 2-5: MacMillan Consumption Chain Example

To understand the customer’s entire experience of a product journey, MacMillan and McGrath begin with customer awareness of the need and end with the disposal of the product, advocating analysis from the customer’s perspective (referred to by designers as empathy). “Although mapping the consumption chain is a useful tool in itself, the strategic value of our approach lies in the next step: analysing your customer’s experience” (MacMillan and McGrath 1997:142–43). The marketing team analyses the consumption chain, seeking to identify the external stakeholders and their needs. Asking questions and conducting follow-up research brings focus to customer needs at each step of the chain. Adopting this methodology, designers can similarly map the entire enhanced product experience from raw material,

manufacturing processes, supply chain, and distribution channel, to recycling opportunities. In this way, design can seek to identify needs of the internal and external stakeholders early in the new-design challenge. This consumption chain analysis of the product experience seeks to identify insights into unmet needs, as well as provide competitive benchmark metrics for the development process.

The designation offered in this study for identifying those competitive opportunities for differentiation in business is the strategic exploration through research into white spaces. Strategically pursuing white spaces focuses the design on those drivers of new value that can create competitive advantage. This discipline of a focused strategic designerly quest is a fundamental element for managing the new product design and development practice. Designers pursue new knowledge in practice when the existing knowledge falls short of solving the challenge. Bringing a strategic differentiating white space focus to this new knowledge pursuit is critical for identifying and creating competitive advantage. Research is critical for benchmarking the existing product expectations, as well as seeking insights into those newly designed advantages. Innovation is demonstrated when the design strategy competes and achieves the customer-getting distinction in the judgement of the stakeholders.

2.18 The Metric of Product Design Innovation Is Competitive Advantage

There exists a conundrum in the meaning and use of innovation in new product design and development discussions. This meaning confusion has similar etymology issues as discussed previously with the meaning of design. Godin states, “Over the twentieth century, innovation has become quite a valuable buzzword, a ‘magic’ word” (Godin 2015: 287). For the purpose of this literature review, the meaning of innovation will focus on new product innovation. *Innovation* as a standalone term is defined by Merriam-Webster as “a new idea, method, or device” (Merriam-Webster 2014: 645). Confusion arises when this definition applies to commercial circumstances where the new ideas must have implied advantages, versus simply being new. Including commercial product economic success benchmarks as discussed brings an additional higher order meaning beyond any new device or method for product design (Porter, Levitt, Kuczmarski, Miller, Vogel, and Cagan). Logically, just because a design may be new, does not imply that it has established new value over the existing solution.

Researching this dichotomy, Godin, in his book *Innovation Contested, The Ideas of Innovation Over the Centuries*, chronicles the evolution of the term *innovation*. Originally a description of something new, the term has evolved into a word used negatively to attack the changing of the existing order: “In 1548, Edward VI, King of England, issued a declaration *Against Those That Doeth Innovate*. Trials and punishments followed. In the following century, documents by the hundreds made use of innovation to discuss the reformer as heretic” (Godin 2015: 281). Later in the nineteenth century, the connotation of innovator as a radical reformer changed and the implication of beneficial reformer emerged, bringing a more positive than negative view of the innovator. “The next enlargement gave to innovation a positive connotation. In the nineteenth century, innovation condenses or crystallizes into a single word a whole semantic field or cluster of other concepts and ideas: change, novelty, invention, reform, revolution, creativity, originality, utility” (Godin 2015: 282). Joseph Schumpeter brought focus to the economic value of innovation of the 20th century and the meaning again morphed into a focus on entrepreneurial value.

For commercial product advantage, competitive success is a common benchmark for a shared meaning of innovation (Schumpeter, Levitt, Porter, Verganti, Kuczmarski, Miller, Vogel, and Cagan). Beyond competitive success, novelty and invention are also common benchmarks as described by Dahlin and Behrens (2005) in their criteria for identifying an innovation. According to Fagerberg (2003) innovation is also not an independent event; what is considered innovative is often the result of a competitive chain of innovative events that eventually rose to a significant stage and were recognised.

2.19 Literature Review Conclusion

This literature review chapter has reviewed the work of others who have explored the design process. Beginning with a review of the nature of design as possibly a unique aspect of the human experience, and continuing with the design process and how it manifests in practice, this chapter reviewed the designerly characteristics of both the designer and the creative process. One of the more important aspects of this review was to establish a common meaning of design for this thesis as a foundational basis for constructing a rigorous argument. Design is defined as:

Design is how humans seek, conceive, and create new knowledge.

Building off this definition the chapter explores the design performance aspect of the research in the context of how design rises to a new competitively advantaged level in the new product marketplace. It focuses specifically on how business seeks these designerly innovative advantages as the outcome of the investment in the new product design and development process. While the predominant literature on innovation has focused on a business analysis of successful products in the marketplace, the challenge for this research is what can be learned from an analysis of the design process employed to create products with demonstrated competitive advantage in the marketplace. Another important aspect of this chapter is the recognition that it is not the designer or the sellers of new products but it is the:

Only the stakeholders of the marketplace that confer competitive advantage.

Therefore based on the low percentage of new product success from innovative pursuits, it can be argued that competitive advantage is a very elusive goal in new product development, yet quite often companies are claiming innovation for their work. As discussed in this chapter, innovation itself is clouded with mixed meanings and confusing rhetoric throughout the literature, yet it is at the heart of a significant amount of time, effort, and investment for business. This chapter reviewed the innovation literature and sought to redefine innovation for the purpose of bringing focus specifically to the stakeholder judgement of what is and is not innovative design. This study redefines innovation as:

Innovation is when new knowledge achieves competitively advantaged outcomes over the existing knowledge.

3. Methodology Introduction – Rigour in Reflective Practice

I fully agree with you about the significance and educational value of methodology as well as history and philosophy of science. So many people today—and even professional scientists—seem to me like somebody who has seen thousands of trees but has never seen a forest.

Albert Einstein, 1944 letter to Robert Thornton

This autobiographic reflective practice mirrors Einstein's above quote. I practiced in the trees for over thirty years, transitioned out of the trees through teaching 10 years ago, and now reside fully outside the trees in this study. My perspective of design has changed, I have refrained my theory-practice through this research, as my worldview of design as an academic discipline beyond its role in practice continues to advance. I must acknowledge Donald Schön's (1983, 1987) reflection on practice research and its contribution to methodological enquiry for this protocol. In addition, Dewey's and Schön's learning through dialectic reasoning and enquiry on actions and experience provide the thought process logic of this synthesis. The insights of these two great scholars combine as a supporting structure for the Grounded Theory logic as the thesis's methodological framework.

This chapter will develop on the mixed methods of enquiry to facilitate the research questions using a pragmatic philosophical approach. Knowledge gained from experience and action guided this research and synthesis of this knowledge contribution. As discussed in Chapter 1, the potential for bias in researching one's own work is always present, while conversely the unique access to one's own data can actually be a strength for research. Establishing academic rigour while at the same time managing bias is the methodology objective.

Summarizing, this research seeks to explain the design process of creating new value and competitive advantage arising from an exploratory product development practice. This methodology will draw from combinations of mixed methods and a variety of data sources, both qualitative and quantitative, in support of the analysis. A foundational objective argument is that established market validation and commercial viability provide objective confirmation of designed advantage. Although the results are not the product of the scientific method, the product histories are outcomes validated quantitatively in the laboratory of the competitive marketplace.

3.1 Research Design – Summarizing the Study

3.1.1 Context for the Research of Practice Methodology

The past practice of my product development work began with a scientific-based (engineering), positivist philosophy of problem solving in the early years and evolved into a design-based pragmatic philosophy of problem solving as I gained proficiency. This evolution stemmed from my realization that the disciplinary-based application of existing knowledge to new design problems, although appropriate in many contexts, takes a practitioner only so far in practice. Whilst practitioners are principally engaged in the disciplinary best practices of their work, they do at times find themselves in circumstances where their disciplinary knowledge falls short when solving new problems or addressing new challenges.

The day-to-day practice of engineering design or other disciplinary practices such as medicine or research in the sciences, requires strict adherence to best practice rules and established protocols built on validated knowledge of the professional practice. Practice for the most part follows the rules of the best practices. This paradigm-confirming best-practice protocol is necessary to ensure quality, consistency, and safety in most practices. At times however, when confronting new challenges, this existing disciplinary knowledge in all paradigms falls short in practice, and there is a gap. I have experienced this gap many times in practice, and I now recognise it as the starting point for the creation of new practice in creating new solutions. The design process at this stage must seek, conceive, and create the new rules of practice.

3.1.2 Patents as One Source of Primary Quantitative Objective Data

This research is focuses on the designerly enquiry in seeking, conceiving, and creating commercial competitive advantage by employing a strategically differentiated design practice. In new product design, invention and resulting patents are metrics associated with novel products. Although patents alone are not reliable indicators of competitive advantage, this protocol design argues that their historical records can be so, if the patented products resulted in a successful market presence as previously discussed. Currently the author's past practice has produced 40 U.S. patents and 100 combined U.S. and international patent filings arising from the strategic design process.

Furthermore, patents serve a particular role in society; they are a form of intellectual property that undergoes a rigorous professional examination of both the existing knowledge space and discovered new knowledge contribution. A patent is certainly a bright line of objective quantitative data that indicates new knowledge of the technology. Successful products have a technical and protectable competitive advantage in the marketplace. The case histories chosen for this study have prior art patents as well as new patents created by the author to provide multiple sources of objective information focused on the product problems and solutions of the cases.

3.1.3 Competitive Advantage is a Quantitative Objective Evidence

Whilst technical inventions can be powerful new product differentiators, they are only one of many differentiating opportunities in the design process that can give rise to competitive advantage. As discussed in Chapter 2, products that have succeeded in the marketplace have undergone a naturally selective competitive commercial challenge. Researching the design process of how those products evolved will logically offer revealing insights into their design processes. This competitively selective evolutionary process of the marketplace has objectively selected the competitively advantaged products (and their respective design processes) over those that have fallen short in competition. This commercial naturally selective process is both objective and quantitative evidence for the research.

3.2 The Theory and Practice Dichotomy in Design

In theory, theory and practice are the same. In practice they are not.

Anonymous

The contradictions often found in practice when reconciling the theory of that practice continue to challenge both academics and practitioners alike as so elegantly expressed in this famous quote above. Holmström, Ketokivi, and Hameri, in their article “Bridging Practice and Theory,” say: “Despite ambitious efforts in various fields of research over multiple decades, the goal of making academic research relevant to the practitioner remains elusive; theoretical and academic research interests do not seem to coincide with the interests of managerial practice” (Holmström, Ketokivi, and Hameri 2009: 1). Whilst this quote is taken from a paper discussing operations management, it advocates for a design-based approach for seeking research methods to create more relevance for researching and explaining practice explicitly

in management. It is a similar challenge for this study to contribute new theory on the design that resonates in practice.

In addition, I would argue that an insight that has been discussed in operations management research also exists in design practice research, “It is indeed the practitioner – not the academic scientist – who engages in basic research in OM” (Holmström, Ketokivi, and Hameri 2009: 1). This paper addresses the challenge of researching qualitative subjects such as operations management (and similarly design) in an academically rigorous way. Still undetermined will be the success of the practitioner based academic research in both operations management and design and how the new theory can improve practice.

In the design practice space, Friedman writes about the problems of creating design theory out of practice with academic research. Practitioners rely on the tacit research knowledge in practice, whilst academic research has its own methods and methodologies of researching a practice. The categorization of the two different research methodologies creates a confusion, “Design theory is not identical with the tacit knowledge of design practice. While tacit knowledge is important to all fields of practice, confusing tacit knowledge with general design knowledge involves a category confusion” (Friedman 2003: 519). Researching design practice to create new theory from practice must involve study of a designer’s tacit knowledge of practice, employing rigorous academic methodologies.

A complication and another potential confusing factor is that academic research of a natural science like physics, biology, or chemistry is a very different methodology than researching a qualitative discipline like the design process. Design is not anchored in natural laws or in directly quantifiable data that can be observed, correlated, and analysed. Researcher access to data and experience in interpreting may also challenge researchers, as alluded to in operations management discussion (Holmström, Ketokivi, and Hameri). Possibly, when researching such a qualitative process as design when compared to the quantitative natural sciences there is a yet to be understood dynamic. Can it be that academic researchers without having had the practical experience and proficiency of design practice are at an experience and worldview disadvantage when seeking to understand and explain the tacit nature of design practice?

Archer also addressed researching the process of design practice and our challenges using traditional academic methodologies. Archer writes, “Studies of the methodologies of art or design fall within the crosscutting discipline of design research, which embodies several kinds of research. All studies about practice, if they are to be recognized as research studies, must employ the methods, and accord with the principles, of the class to which they happen to belong” (Archer 1995: 13). Archer addresses the academic research of tacit knowledge domains such as art and design. Further, addressing the differences between research in design practice and academic research of practice, he writes, “It is not quite so certain, however, that the practitioner activity itself is quite the same as research activity, however much research it may have been supported by” (Archer 1995: 13). Reconciling this activity difference is necessary for understanding how they can inform one another.

Cross further addresses academic design research in the context of design practice, bringing focus to the use of rigorous academic methods, methodologies of research, objective analysis, and evidence-based reasoning arising from the data. “*Purposive*, based on the identification of an issue or problem worthy and capable of investigation; *Inquisitive*, seeking to acquire new knowledge; *Informed*, conducted from an awareness of previous, related research; *Methodical*, planned and carried out in a disciplined manner; and *Communicable*, generating and reporting results which are testable and accessible by others” (Cross 1999: 9). Summarizing Cross, the basis of academic research of design practice has the following criteria. It is:

- **Purposive**, seeking new theory of value and competitive advantage creation by the design process of successful products.
- **Inquisitive**, by focusing on explaining how the design process of an expert designer created three case histories of competitively advantaged products.
- **Informed**, as the academic researcher is also a recognised expert practitioner and professor of design.
- **Methodical**, because the academic researcher is supported by a director of studies and committee well experienced in academic research.
- **Communicable**, evidenced through creation in support of its worthiness as a study, defining the heuristic process of the research, including a synthesis of a new knowledge creation framework presented in Chapter 5.

In addition to the contribution to new knowledge, a secondary opportunity for this study is to establish a path of professional explanatory academic research exploration of proficient design practice. Potentially, future experienced design practitioners with similar backgrounds, researchers pursuing doctoral programmes, may find an academic research pathway in building on the work of Archer, Cross, Friedman, and the many others in the design community seeking to further develop design as an academic discipline, through the academic research methodologies best suited to disciplinary knowledge creation. “This discipline seeks to develop domain-independent approaches to theory and research in design. The underlying axiom of this discipline is that there are forms of knowledge peculiar to the awareness and ability of a designer, independent of the different professional domains of design practice” (Cross 2007: 46). Arising from my many years of practice and now almost 10 years as an academic, undertaking this research is at the core of what many design researchers have been discussing: research insights seeking to make explicit those forms of designerly knowledge of practice in the form of new academic theory of design practice, that can inform both practitioners and academics.

3.2.1 Summary of Pragmatism Methodological Paradigm

Research of philosophical paradigms has guided me to pragmatism as the philosophy that best aligns with my worldview and the subject of this research. The chart below from the work of Milman created for a course in research (see Table 3-1), although never published, clearly illustrates the differences in philosophical paradigms. Milman describes the philosophical paradigm of pragmatism as a dialectic rationale built on both objective and subjective views of real world activities, one that uses both qualitative and quantitative data and methodologies to find a philosophical truth of knowledge.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Table 3-1: Chart From Milman (2010).Class on Qualitative Research Course Slides

Summarizing Milman on Pragmatism:

- Dialectic forms of enquiry and reasoning
- Ontology constructed based on the world we live in and explanations that produce the best-desired outcomes.
- Epistemology-based objective and subjective points of view as evidence
- Methodology built on both qualitative and quantitative data availabilities

Milman has articulated the nature of the designerly pragmatic paradigm compared to the other conventional paradigms based on my design experience.¹

¹ Note for the Milman table:It was necessary to correspond with Milman directly in order to cite the original creation of the text. She advised me that it was a class slide for a course she no longer teaches. The slide is posted on an education-focused web site titled "Nadis Island" where I accessed it.

3.3 Pragmatism in Design Practice and the Research of Practice

When looking back on my design practice, I realised I was tacitly combining a constructivist qualitative (interpretivism according to the Milman chart) research philosophy at the front end of my design process. Once I was able to research and establish the project stakeholder needs and requirements, I unconsciously pivoted to a positivist perspective of creative problem solving often relying on my technical practice techniques. In the cases where there was a lack of information necessary to move forward, I again pivoted back to the constructivist thinking in researching the opportunity spaces, pivoting back once again to positivism to test and validate these potential solutions. This iterative philosophical pivoting as dictated by the challenge is necessary for design, as it cannot rely solely on a single philosophical paradigm.

On reflection, I now see how the positivistic nature of my undergraduate education provided me the starting point for my design work as a technical problem solver. As my challenges and experience grew, so did my proficiency in design, although this required an explorative, less structured philosophical approach that was much more constructivist. Achieving a proficiency in design required adapting to this hybrid pivoting of philosophical approaches to the challenge as I struggled to seek white space differentiation through my design practice. I see a similar white space academic contribution connection.

This doctoral research has challenged me to study and articulate a research philosophical paradigm for researching a designer's practice. It is now obvious to me that the pragmatist approach to design practice is also my approach to this research of design practice. As stated previously, this academic research has a familiar design project feel for me. I now recognise that the familiarity arises from the mixed qualitative and quantitative methods of enquiry, as well as the dialectic process of reasoning shared by both my design practice and now my research of that practice.

Thus, I evolved as a practitioner from a scientific method-focused problem solver in my early years of practice to a design method-focused problem solver in my later years as I acquired broader business experiences. Now when seeking to develop new theory from the research of design practice as a new knowledge contribution, I have chosen to rely on the same pragmatic philosophical approach to methodology and reasoning; as I can comfortably state now, they are similar research processes.

3.3.1 Pragmatism in Other Doctoral Design Studies

When researching existing doctoral theses, I found few that have similar conditions for conducting design research around professional past practice. A number of theses look into the practices of others; there are only a few that I have identified to date in which the researcher is also the practitioner. One is by [Stompff \(2012\)](#), in which he researched how design teams interact in facilitating team cognition. In reviewing his thesis, I was encouraged that he had also chosen a pragmatic methodological paradigm as the one that most agreed with his methodical enquiry. “Pragmatism is a tailor made paradigm for reflective practitioners” ([Stompff 2012: 48](#)). For his thesis, Stompff created the chart below (see Table 3-2) to summarise an overview of the paradigms of enquiry of a practitioner-researcher; I will rely on this chart for my discussion of pragmatism for a pragmatist philosophy of enquiry.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Table 3-2: Stompff Thesis “Overview of Relevant Scientific Paradigms” (Stompff 2012: 44)

In this chart, it appears that Stompff chooses to use the term rationalism instead of positivism; the two are often interchangeable when discussing paradigms. Pragmatism is abductive (logical inference from observations) based on objective reality and practical knowledge, such as observed in the competitive product spaces. In addition, one can view this work from two perspectives: research into the practice in real time as an artefact is created (action research) as in Stompff’s thesis, or reflective research into how artefacts were created previously, as in the reflective practice enquiry of this study. The research of this work departs from Stompff, as his

thesis uses action research of which he was a participant/researcher: researching his thesis at the same time that he was participating in the research.

Pragmatically, this research builds on the experience and action of the real world (ontology) (Dewey and Schön) through objective evidence of commercially successful products detailed in the case histories practice (epistemology). A protocol of analysis and synthesis of the evidence-based data collection (methodology) provides context for the analysis of one's own work (reflective practice) through reflection on dialectic thinking (Hegel and Schön), supporting the new knowledge contribution (see Figure 3-3). . An interesting aspect of reflective learning shared by pragmatic philosophy is that the new knowledge evolves through the reflection on actions and experience, not necessarily during the actions, experiences, or synthesis themselves. This reflective-based, dialectic, cognitive synthesis of existing and new knowledge states is a key insight into creativity and knowledge creation, and is an integral part of the designerly form of enquiry (Hegel, Dewey, Schön)



Table 3-3: Thesis Philosophical Foundation Chart

3.3.2 Autobiographic Practice-led Nature of Researching Practice

The objective of this chapter is to map out the research methods, philosophical perspectives, and research frameworks as noted in the methodology conclusion (see Figure 3-10). The research focuses on the question of how design creates new product value and competitive advantages in the marketplace. This research is the explanatory analogue of an exploratory industry practice of three new product

development cases of my own practice. It seeks to make explicit the significant tacit knowledge in the practice of design. As Pedgley, another action researcher of the design process, states in his thesis:

Practice-led research is a mode of enquiry in which design practice is used to create an evidence base for something demonstrated or found out. It involves a researcher undertaking a design project subservient to stated research aims and objectives. Thus, the main motivation of practice-led researchers is to elicit and communicate new knowledge and theory originating from their own design practices. Its pursuance of course requires that the researcher is also a skilled designer and is prepared to combine the two roles of scholar and designer: something that is known to be intellectually challenging. (Pedgley 2007: 463)

Pedgley a researcher who earned his doctorate using practice-led research has identified three modalities of research:

1. Find out about current design practices (e.g., pursue a design project to help uncover decision-making processes and social responsibilities).
2. Devise improvements in design methods (e.g., pursue a design project to help conceive and develop new design procedures, information, priorities, and tools).
3. Make improvements to designed artefacts (e.g., pursue a design project to help contribute to how a type of product can or ought to be designed, how it can be improved, and to demonstrate benefits).

(Pedgley 2007: 464)

Pedgley discusses the controversy of this type of methodology, where he used the reflection in action method of action research on his polymer guitar design and development. He cites potential criticism of this methodology in relying on autobiographical qualitative methods to provide reliable data. The answer for Pedgley is a robust and detailed diary of the design process of his action research. As previously discussed, this nature of bias is always present in research; it must be managed. Therefore, in this study, I have sought to incorporate quantitative data to support qualitative data in a mixed methods approach to manage this bias. Although similar studies using practice-led research, this study differs from Pedgley in a significant way. The case histories have quantitative data arising from the practice, in support of the qualitative data and as evidence of competitive advantage. Thus, this

study creates a possible fourth and fifth modality in addition to the above, based on the reflective practitioner-researcher models of successful products arising from practice:

4. Explanatory research of the designerly strategy and heuristics of practice, through auto-ethnographic research of successfully designed solutions in the marketplace.
5. Action research, utilizing the designerly strategy and heuristic theories of practice, through the exploratory development of new products in practice that are selected purposely for their intended competition in the marketplace.

The above potential new research modalities suggested by this study obviously self-selects experienced researchers who are in a position to pursue academic research of past practice. These steps are further discussed in Chapter 5.

3.4 Research Plan Built on Case History Protocol

Case study is the primary research methodology, and the three case histories are central to the research plan. It should be noted that unlike a study built solely on qualitative data, this study has significant quantitative data to support the reflective narrative, as is detailed in the case histories in the appendix. This case history evidence is supported by archived documents in the patents, market literature and sales data, and design and innovation awards as well as sustainability in the marketplace as evidenced by the current commercial availability. In *The Reflective Practitioner* (1983), Schön describes reflective learning from actions, highlighting two distinct paths – reflection in action and reflection on action – noting that at times both forms of learning are in play depending on the circumstances of the reflection. It appears that most reflective practice is reflection in action, such as action research or ethnographic research, while this study relies on reflection on action, supported by the objective historical data in the case histories.

3.4.1 Axiology of Study

I have included an axiology perspective as part of my research methodology model. Although this is not a traditional consideration, the concept of axiology addresses the value contribution of this work. Recognizing that bias would destroy the value of any new theory, the recognition and control of bias forms the axiology.

The approach to bias control is first to recognise that it exists and make it part of my consciousness. Second, I rely on quantitative-based historical evidentiary support and logic constructs rather than relying solely on qualitative reflection and narrative. Thirdly, the choice of more than one case provides additional evidence of product design with objective market success. Lastly, market success fundamentally supports the reflective narrative argument for new value and competitive advantage creation from the three cases. The narrative is thus the explanatory support of quantitative evidence created by the case histories, not simply relying on unsupported narrative reflections.

Summarizing the Axiological Guard Against Subjectivity and Bias

As first discussed in Chapter 1, designing a methodology to support an objective truth for this reflective practice on the surface is challenging. Existing design-research methods and methodologies have evolved to serve researchers who typically interact with data from other sources in an ethnographic research setting where the researcher is an observer independently documenting the data of others. Alternatively, there is action research of case data arising in practice employing protocols such as in the Stompff and Pedgley studies. Conventionally, the independent data-researcher relationship separates the researcher from potential conflicts of interest or bias introduction of data. Whilst there is no evidence to support or deny this perception, the goal should be to rely on quantitative, independent data for objectivity, where possible, as the guard against bias.

For objective rigour, and to guard against autobiographical hindsight bias, the design of this research relies on multiple quantitative data sources that are structurally independent in support of the reflective narrative:

- U.S. patent records
- Historical design and engineering records
- Historical marketing literature
- Historical new product award data
- The artefacts and their derivatives created by the design process

This quantitative data is supported by my reflections and by third-party interviews of informants having first-hand knowledge of the case histories. The case histories were organised and supported with the above quantitative records where appropriate.

3.4.2 Ontology of Study

The ontology for this methodology can be framed in the context of how design interacts with the marketplace and the competitive outcomes of design as evidence-based data for my research. The stage for this study is not a traditional laboratory, but the real-world clinical laboratory of the marketplace for the products. Although my product choices were successful, that alone is not sufficient for new theory contribution for doctoral research. New theory depends on rigorous academic research, analysis, and synthesis of new theory arising from this research of the product design process for creating those commercially successful products.

For the creation of new theory in design research, as Cross, Friedman, and others have written, the methods and methodologies must be robust and accepted sources of evidence. Cross has discussed the suitability of practice for research, stating, “This does not mean that works of design practice must be wholly excluded from design research, but it does mean that, to qualify as research, there must be reflection by the practitioner on the work, and the communication of some re-usable results from that reflection” (Cross 2007: 48). This research is one such example of this research of design practice.

In *The Practitioner Researcher—Developing Theory from Practice*, Jarvis discusses the trend in practitioner research arising from many practices and the changing face of research of practice. He states, “But this is a practical age when knowledge is legitimated by its performability, and much of the knowledge we learn must be relevant and practical. Researching the practical world of work—whether routine production, service-based industries, knowledge-based industries, or whatever—is a demand to which every organization that wishes to maintain its place in the global market must respond” (Jarvis 1999: 186). Jarvis embraces a pragmatic perspective arguing that the performance of the practice-based knowledge is itself a legitimization of the study. He emphasises the point that, in order to advance knowledge for practical industry applications, we must research these practical and relevant sources of knowledge.

Jarvis also contends that practitioner-researchers have unique access to the data they are researching. As stated previously and as supported by Jarvis, “Practitioner-researchers have potential access to a wide variety of documentary material, much of which is ‘insider’ information ... This documentary evidence

provides greater insights into practice and practice situations” (Jarvis 1999: 118). From my experience, this is true; beyond the quantitative historical data, the insider’s insights of the moment when decisions are made provide a rich view of the strategic use of design that does not exist elsewhere. Importantly the quantifiable data should support the logic and rationale of the reflective narrative to provide credibility.

3.4.3 Epistemology of Study

Compared to other methods of evidentiary claims in reflective practice research, where the researcher must rely only on qualitative methodology, this examination offers quantitative evidentiary support. Stakeholder confirmation enabled by the success in the competitive market is an objective and quantifiable source of data. Thus, as previously discussed, the checks-and-balances argument for evidence of designed advantages of the case studies (market viability) is the sustained and proven marketplace performance of the three cases. This marketplace validation is uncommon, yet the fact that it exists supports the evidentiary claim of designed advantage for the cases. For design cases of this study, market viability as objective evidence combined with the insider perspective supported by historical data offer unique sources of evidence on which to base this academic research.

Jarvis, responding to Guba and Lincoln (1981), addresses their opinion relating to the unreliability of case studies: “oversimplification, exaggerations of the facts, and interpretations of selective facts; they are unscientific, opportunistic, and unrepresentative; and they are partial accounts masquerading as full accounts” (Jarvis 1999: 82). Acknowledging these potential shortcomings as the nature of cases outside of controlled experiments, he emphasises that it is the role of the researcher to identify and examine the validity in all research, especially in studying practice in the wild, offering, “Because practice is transitory, the case study is the most reliable way of studying it” (Jarvis 1999: 86). In recognition of these opposing perspectives and their respective positions, the evidence for case study data must be developed in a rigorous manner as in all research, to achieve objectivity and rely on objective quantitative evidence in support of the qualitative data. The research protocols and validity strategy will be discussed later in this chapter in 3.6.

3.5 Case Study as the Primary Research Method

The consideration of which research methods to use must take into account the nature of the research topic; the academic discipline's culture; the nature of the data available to the researcher; and the objectivity of the data, its source, and its validity in support of an academically rigorous research process. The challenge is to identify the appropriate methodology and methods that “fit” with the research plan and build on established protocols for conducting similar research in a scholarly referenced process. A challenge for this research protocol is the lack of established protocols.

My exploration of methods for the protocol of reflective practice-led research has taken me through both qualitative and quantitative examples that are based on a variety of theoretical foundations. I did not find any exact examples on which to build my research plan, not surprisingly since not many doctoral researchers are starting academic research after 30-plus years of practice. Therefore, I have been challenged to explore both traditional and emerging methods to create the most appropriate methodology. As my primary method to researching practice, I have chosen case study. Jarvis has observed, “The practitioner-researcher's research situation is always a particular situation, and for this reason it can be researched only as a case study.” (Jarvis 1999: 85). Seeking to compensate for the lack of existing protocols, I have chosen to study three cases of successful past practice.

Stake suggests six aspects of case study for providing specialised data:

- The nature of the case
- Its historical background
- The physical setting
- Other contexts, including economic, political, legal, and aesthetic
- Other cases through which this case is recognized
- Those informants through whom the case can be known (Stake 1994: 238)

These aspects may not be present in every practitioner case study, Stake says, but they are common elements. Similarly, Jarvis commented that: “Case studies form part of the knowledge of practice of any occupational group—part of its ‘body of knowledge’—but they are conducted in totally different ways” (Jarvis 1999: 87). Case studies do provide the objective reliability from the laboratory of the real world, while mixed methods of research raise the objective validity (see Table 3-4).

CASE STUDY RESEARCH

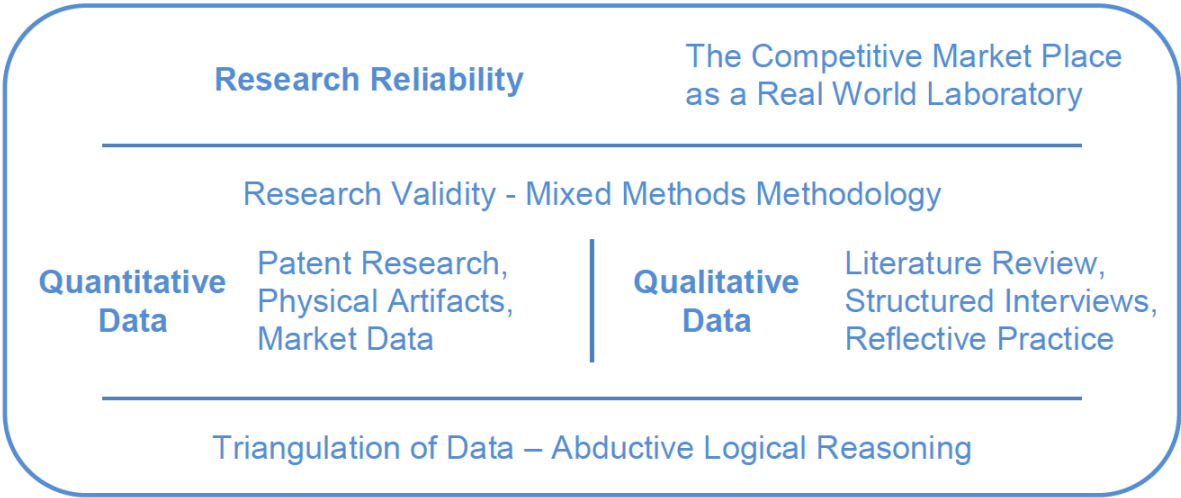


Table 3-4 Organization and Development of the Case Studies

Development of a Case History Protocol

For comparison, I have organised the three case histories in a sequential representation of the data as outlined below (see Figure 3-1). I could not find an example of another product design research protocol relying on this autobiographic case history context, so I was challenged to design the case history protocol to act as a guideline for presenting the cases in the Appendix. These cases are clearly different, but each case does share enough systematic similarities, evolving out of the design process nature of the cases, to create a workable framework for their presentation.

Upon completing the research, I believe that case histories and their related evidence, employing either action research or reflective research, provides the best form of practice-based data on which to study practice-design relationships. The advantage for cases that have competed in the marketplace is the higher expectation of an implied validity from the success of the designed artefacts of the cases to support the data of the research.

Case History Organization Framework



Figure 3-1 Case History Organizational Protocol and Framework Created by Author

3.5.1 Three Cases on New Product Design in the Marketplace

Summarizing, these three chosen cases are of products I created in my past practice. Each case has stood the test of time in the marketplace, providing evidence of sustained viable competency design advantage. Quantitative evidence of my design process exists in data: the market data discussed previously as well as actual designed artefacts. Additional qualitative data exists in my reflections on the design process supported by interviews of informants involved in the case.

Having no pre-existing studies to guide me, I have relied on the Yin case study references and practical experience to compile the following choice criteria for cases:

- Arises out of the past practice of the researcher
- Represents the design process of the research questions
- Has patent documentation as a historical source of data
- Has market-driven opportunities that had direct competition
- Has market based empirical-data to support narrative data
- Can be collaborated by first-person informants
- Has data that has the ability to be triangulated
- Has additional data in the public domain
- Has cases with proven competitive marketplace viability
- Has practitioner-researcher insights and access to the data

The research does not rely on products that did not go to market or that went to market but did not sustain a commercial business, to bring a focus on the strategic design heuristics and drivers that succeeded in creating commercial competitive advantage. Each case has patent documents, market documentation, award recognition, and informants as well as the artefacts themselves to strengthen the data in a quantitative respect to act as evidence in support of the qualitative reflections.

3.6 Case History Evidence in Support of Case Study Validity

Again, I relying on Yin and his book *Case Study Research Design and Methods* (2014) to guide the choice of evidence. Yin maintains that all case circumstances are unique, and this study is no exception. It is the researcher's design of the study according to an accepted standard of academic rigour that is essential. Yin stated when referring to the data sources for case study design, "note that no single source has a complete advantage over all the others. In fact, the various sources are highly complementary, and a good case study will therefore want to rely on as many sources as possible" (Yin 2014: 105). Thus, documentary evidence and the level of objective

certainty of the evidence collectively build and support an argument of the quality and certainty of the data. Yin created the chart below (see Table 3-5) to outline some select forms of evidence. This study has incorporated documentation, archival records, and physical artefacts. In addition, direct observation and participant observation are used. The study is in the form of reflection on action, versus reflection in action, as previously discussed. As Yin pointed out, there is always potential for bias in the direct and participant aspect of the data, but, as discussed previously, bias was recognised and managed in the research plan.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Table 3-5: Yin Six Sources of Evidence for Case Study Methods (Yin 2014: 106)

3.7 Establishing Validity into the Case Study Protocol

Yin in his book *Case Study Research: Design and Methods* (2014) describes five components for judging the quality of case study research design: “a case study’s questions; its propositions, if any; its unit(s) of analysis; the logic linking the data to the propositions; and the criteria for interpreting the findings” (Yin 2014: 29). These five components work together to support four goals of a robust research design; these goals are *trustworthiness, credibility, confirmability, and data dependability*. Yin created the table below in support of the five components (see Table 3-6).

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Table 3-6: Case Study Tactics for Four Design Tests (Yin 2014: 45)

The chart below (see Table 3-7) compares Yin’s four case study design tests (see Table 3-6) with the case study design of this research. Whilst data derived from a structured experimental methodology has the advantage of controlling the variables in its method, researching the design process does not lend itself to these experimental methodologies. Arguably, there are times where data validity can be quantitative for designed products often around functional attributes. Data validity for the non-functional and often-qualitative emotional and behavioural aspects of design must rely on the performance of the design outcomes.

ANALYSIS OF THE CASE STUDY DESIGN COMPARED TO LIN PROTOCOL

Construct Validity	Use multiple sources of evidence <ul style="list-style-type: none"> - Patent records - Market data - Market records - Artifacts of the design process - Semi-structured interviews - Autobiographical reflections 	Yes
	Establish a chain of evidence <ul style="list-style-type: none"> - Written case studies 	Yes
Internal Validity	Do pattern matching <ul style="list-style-type: none"> - Thematic analysis 	Yes
	Do explanation building <ul style="list-style-type: none"> - Reflective narrative 	Yes
External Validity	Use case logic <ul style="list-style-type: none"> - Three cases analyzed 	Yes
Reliability	Use case study protocol <ul style="list-style-type: none"> - 10 step protocol (3.4.2) 	Yes
	Develop a case study database <ul style="list-style-type: none"> - Written case studies 	Yes

Table 3-7 Correlating Yin Criteria with this Thesis Case Study Criteria

3.8 Triangulating the Data Sources for Case Development Evidence

There are multiple methods of data triangulation as cited by Yin in his book *Case Study Research* (Yin 2014), where Yin refers to Patton (2002), describing the various methods of data triangulation from multiple sources of evidence:

- of data sources (*data triangulation*),
- among different evaluators (*investigator triangulation*),
- of perspectives to the same data set (*theory triangulation*), and
- of methods (*methodological triangulation*) (Yin 2014: 120)

The data for the case studies conform to the evidence category one, the triangulation of data from several data sources. Yin further encourages building case studies from multiple data sources as in category one, but, if possible, including a strategy of converging the evidence, allowing for corroboration of the data in support of the case. An additional strategy for raising confidence is to review data from multiple cases where comparisons are consistent and relevant.

3.8.1 Market Data as a Quantitative Data Source

I have selected my cases for their inventive design and patent legacies, allowing for the use of historical patent records as a rich source of quantitative data about the design process. The differentiators of each case that created value resulted from the strategic design process of my practice, providing examples of objective data for research. In addition, the first-person reflection on one's own design work offers the ability to reveal data and insights beyond information provided in patents, historical documents, and market data. This access to strategic design process information is a unique qualitative complement to the quantitative patent, historical records, and market data of this research.

3.8.2 Historical Patent and Market Data as a Quantitative Data Source

This patent-based history is a source of both qualitative (in its similarity to a literature review) and quantitative (in its disclosure of the technical history, problems, and novelty) data. Defining the prior art provides an evidentiary reference to the existing technical market conditions of the cases. Supporting this claim, Benson and Magee state, "Patents are an attractive choice for analysing technological change because they are: generalizable, objective, quantitative and qualitative" (Benson and Magee 2015: 2). Patent documentation is but one of several areas a researcher can

explore for archival historical data of a case. This research therefore draws on patents as quantitative sources of historical data. Other similar possibilities include competitive market data, marketing data, editorial data, and feedback on the product, as well as research into any competitive awards the product design has received.

3.8.3 Informant Interviews as Sources of Evidence

To augment the quantitative data of these cases will be the reflective narrative in support of the autobiographical descriptions of the design process. This includes semi-structured interviews conducted with individuals having first-person interactions with the researcher during and after the design process of the case studies. Rubin and Rubin have observed that interviewing informants is a rich source of information, and that the nature of case study informant interview resembles guided, fluid conversations rather than structured, rigid enquiries (Rubin and Rubin 2011). As the primary source of data is case histories for this study, further support of the reflective narrative of the practitioner-researcher relies on unstructured interviews. Five interviews averaging two hours in length created very rich discussion and remembrances of past mutual experiences that were by far the most rewarding aspect of this research. The interviews were recorded and the dialogue transcribed for the record. Following the interviews, the transcribed records underwent an open thematic coding process to identify themes.

3.9 Grounded Theory

Case and Light, in their paper entitled “Emerging Methodologies in Engineering Education Research”, argue that engineering research, particularly engineering-education research, must broaden the range of methodological options for conducting research, including new methods used in other fields. I found the paper useful in addressing the value of embracing novel methods better suited to the research of this design process. “It is argued that methodological decisions need to be more explicitly represented in reports of research and that researchers need to consider a broad range of methodological options, in particular those methodologies that could be considered to be ‘emerging’ in engineering education research, in order to be able to answer the research questions at hand” (Case and Light 2011: 186). Although Case and Light’s paper addresses engineering education research, the discussion of the methods, especially the logic of seeking out the most appropriate methodology is

appropriate. Based on my research, the Grounded Theory method and philosophy stood out as the most appropriate for approaching this research.

I have identified a grounded theory-based methodological process for research protocol and analysis. The challenge was to choose the appropriate reasoning and analysis protocol methodology and integrate it in a strategic complementary design for triangulating the mixed sources of case data. The chart below summarises the various options for methodological approaches to analysing data (see Table 3-8).

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Table 3-8: Methodological Paradigms demysqualitativeresearch.blogspot.com

Grounded theory methodology involves the discovery of new theory by analysing the data generated through a research lens that purposely avoids starting with a hypothesis, allowing themes to emerge as the research process identifies insights from the study. Having embraced Grounded Theory, new insights emerged from the process that will form the basis of the new contribution to knowledge (see Table 3-9). These insights are beyond the heuristics of the design process.

GROUNDED THEORY METHODOLOGY

Repeatability	Validity	Reliability
Grounded Theory - Reflection + Data Coding + Thematic Synthesis		

Table 3-9 Thesis Grounded Theory Chart

3.9.1 Grounded Theory Process Coding as a Method

Grounded Theory relies on a thematic analysis or coding of data in several progressive stages of examination and re-examination to identify themes from the data that can develop into new insights. Coding is a qualitative analytical method of identifying insights that arise at different levels of logical groupings. Coding creates categories, general themes, emergent novel themes, and finally thematic synthesis of new knowledge contributions from the novel themes if present. For this research, the methodological coding approach brought focus to the heuristics of the design process discussed in Chapter 4. These heuristics did group in themes and challenged me with the question that led to my knowledge contribution: when was I employing my practice skills and when was I employing my design skills in practice?

Whilst science data arises from the knowledge of an explicitly formed natural phenomenon (biology, physics, etc.), design knowledge as data has no such explicit natural-like embodiment awaiting discovery and explanation. Design is also different, and its knowledge base lacks the technical rationality of natural science awaiting discovery and explanation. Therefore, the strategy for this study was to thematically identify those designerly heuristics that designers use in practice when creating new knowledge with value and competitive advantage in the marketplace.

The Grounded Theory approach worked for me, as I researched the 'how' of my past practice to identify the heuristic drivers that I tacitly employed. The process of coding and analysis of data as it evolved in the research did lead me to further questions that allowed me to bring focus to heuristic themes. At this point, the clarity of the process prompted me to ask myself: when was I practicing and when was I designing using these heuristic themes? The CAM model and knowledge creation framework of the thesis contribution as seen in Chapter 5 arose out of this process as a new theoretical contribution from the research journey.

New Theoretical Contribution from Data

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-2 Coding, from *Doing Qualitative Research Using Your Computer* (Hahn 2008: 15)

An example of the different stages of theoretical coding in Grounded Theory is taken from *Doing Qualitative Research Using Your Computer* (Hahn 2008: 15) (see Figure 3-2). The theory of thematic coding is an analysis of the data, structured to give rise to insights into themes based on the coding evolution from raw data to emergent themes supported by the data. Reliability is key, and the coding should reflect the thematic analysis completion in an academically rigorous process. Grounded theory relies on the analysis of data and themes that arise from the analysis to support the claims. Charmaz describes Grounded Theory as a set of methods that “consist of systematic, yet flexible guidelines for collecting and analysing qualitative data to construct theories ‘grounded’ in the data themselves” (Charmaz 2006: 2). This coding of data and analysis did give rise new insights from this research as discussed in Chapter 5.

3.10 Abductive Logical Enquiry and Reasoning

Man has been endowed with reason, with the power to create, so that he can add to what he's been given.

Anton Chekhov, *Uncle Vanya*

There are three generally accepted reasoning paradigms: deductive, in which the conclusion is guaranteed; inductive, in which the conclusion is merely likely; and abductive, in which the researcher takes his or her best shot from an intuitive position. Each paradigm informs a logical approach to a set of information and aligns with the philosophical perspective of the researcher. From a pragmatic philosophical foundation, abductive reasoning as a logical construct agrees with this research paradigm as well as the design process. Abduction is a form of logical inference that begins through observation of the event, process, or interaction and iteratively reflects, challenging the designer to ideate a postulate. In the case of a Grounded Theory approach, abductive reasoning supports the creation of a “pre-hypothesis or postulate” to explain the nature of the observations. This pre-hypothesis is constructed from the relevant evidence that leads to an insight of informed enquiry to proceed based on the hypothetical explanation (see Figure 3-3).

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-3 The Abductive Research Process www.emeraldinsight.com

From the process of this enquiry, I have observed that the seeking of new knowledge, similar to the creating of a new theory, embraces the epistemology of the design process. Though this may appear to be convoluted logic, the relationship yet remains: this academic research of the design process employs many of the research heuristic designerly methods of the design process. The abductive form of logic reasoning is one of those heuristics. In referring to the abductive process of sense

making through synthesis, Kolko states: “During synthesis, designers attempt ‘to organize, manipulate, prune, and filter gathered data into a cohesive structure for information building.’ Synthesis reveals a cohesion and sense of continuity; synthesis indicates a push towards organization, reduction, and clarity” (Kolko 2010: 1). During the research process, I have found that the new-knowledge creation of the design process itself and the knowledge creation of the academic research process of this study share the abductive synthesis that Kolko refers to in his quote.

Abduction first appeared in the late 1800s as a logical form of guessing as described by Peirce. Peirce put forth the idea that the best plausible explanation can serve as a starting point for a logical pursuit. This logic is also foundational to the Pragmatist philosophy, described as the abductive designerly process or designerly method that could be the front-end of an idea, or best explanation for creating a hypothesis. Abduction is also the logical foundation for Grounded Theory, and thus serves as appropriate reasoning. Although beyond this study, it may quite possibly be that all logic of a designerly knowledge creation nature arises from an abductive form of enquiry, evolving towards a solution, versus knowledge creation based on an existing phenomenon awaiting discovery and explanation.

For this study, the abductive logical mode of enquiry is consistent from the pragmatist Grounded Theory philosophies, supporting the methodological paradigm as well as the design process itself. Cross states in his book *Design Thinking* that “The more useful concept that has been used by design researchers in explaining the reasoning processes of designers is that design thinking is abductive” (Cross 2011: 10). This abductive approach to logical reasoning is different from the more familiar concepts of inductive and deductive reasoning: it is designerly by nature and occurs in the reflection of one’s practice, the designer’s logical method when formulating new knowledge. Similarly, the abductive form of logical reasoning agrees with the previously discussed Deweyan enquiry and Hegelian Dialectic models of thinking, as it allows for that reflection on the actions and experiences observed in practice to evolve into new models that can be articulated and tested.

3.11 Methodology Conclusion

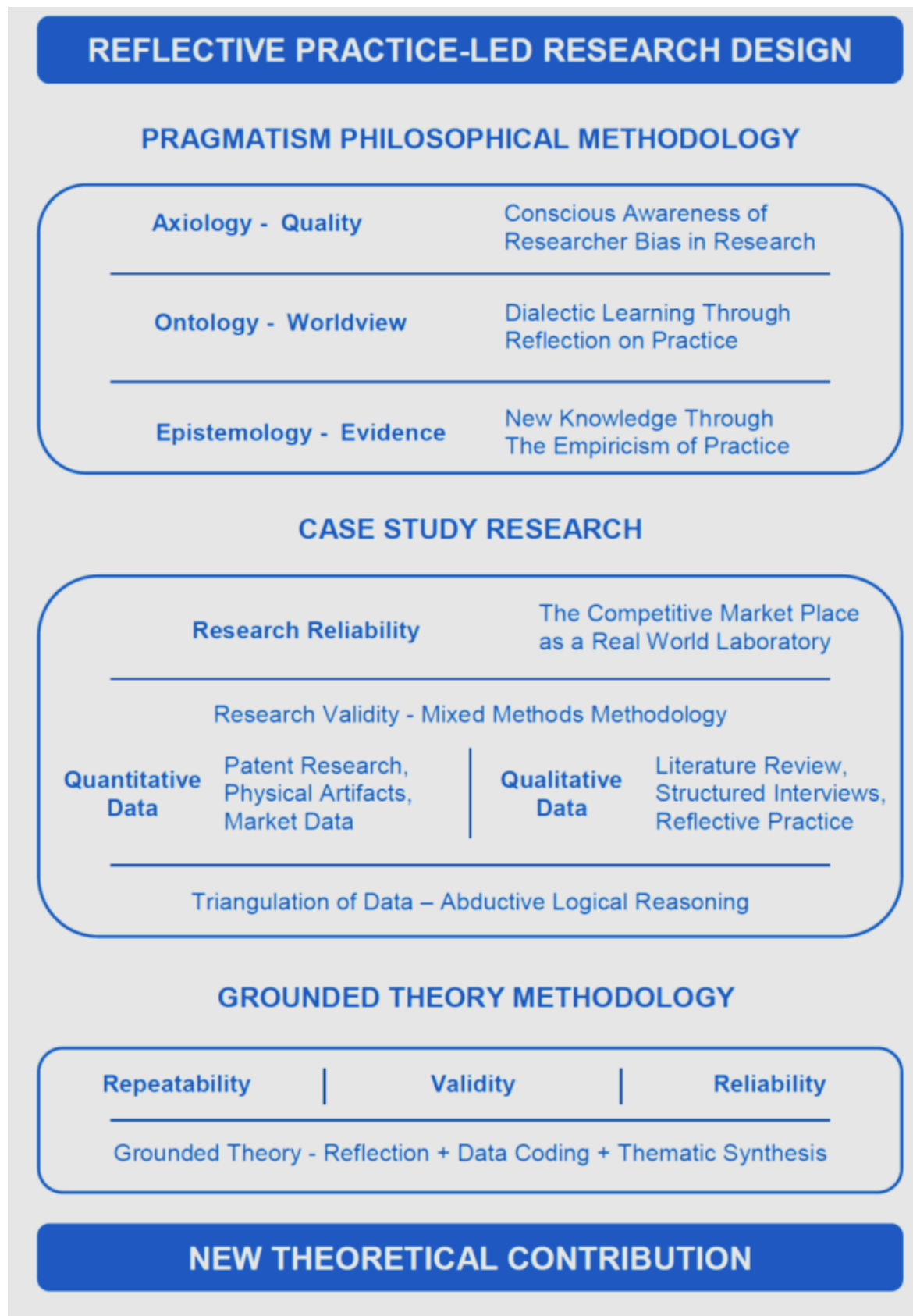


Table 3-10 Methodology Summary Chart Designed and Created for this Thesis

4. Insights Emerging from the Research of Practice - Introduction

I believe that we learn by practice ... It is the performance of a dedicated precise set of acts, physical or intellectual, from which comes shape of achievement, a sense of one's being, a satisfaction of spirit ... Practice means to perform, over and over again in the face of all obstacles, some act of vision, of faith, of desire. Practice is a means of inviting the perfection desired.

Martha Graham, "An Athlete of God"

4.1 Researching the Practice – Design Relationship in Disciplinary Practice

In this chapter, I will present the analysis of the data researched in this study of a professional disciplinary practice. In a disciplinary practice, such as an engineering-design practice or Martha Graham's dance practice in the above quote, actions are by nature (and necessity) paradigm-confirming endeavours. Expert practice in the discipline requires the proficient execution of skills in situations or problems using existing knowledge, evidenced by existing best practice solutions. Reflecting on my practice and reconciling the reflections with the research data developed through this study gave rise to the question: when was I practicing my discipline by following the discipline's rules (using existing knowledge), and when was I designing and seeking to create the new rules of practice (creating new knowledge)? This study brings intense focus to this aspect of a professional's dialectic interaction in practice, bringing focus and framing the interaction on the knowledge gap encountered in a professional's practice.

Seeking in this study to define this symbiotic practice and design relationship, I struggled to define a common meaning with the existing models, as they did not fit my experience. I recognised that, in practice, a transformation occurs of the practitioner's role when seeking new knowledge of practice within a discipline. This duality of the practitioner-designer role is a dynamic interplay in all disciplines, where design behaviours are a practitioner's response in practice to the knowledge gap at hand. Design proficiency, similar to practice ability, varies by experience and skill levels, and Graham as suggested in the quote above, the pursuit of a disciplinary proficiency invites the perfection desired! This chapter will end with a description of the heuristics of this design proficiency of how designers proficiently address this knowledge gap in practice.

I want to note that I am not advancing the notion that design is the process of deviating from accepted professional practices without reason or validation. Deviation

from a practice that has an established history and accountability can be an unethical and dangerous pursuit in itself, accompanied by unintended negative consequences for the stakeholders. This argument distinguishes the design process as the onset of creating new best practices, subject to validation and professional testing, in compliance with regulatory and industry standards of the disciplinary practice. Professional design practice dictates that these standards for safety, environmental, social, and other requirements be ethically considered as the foundation of a professional best design practice. Validation is a key component of new practice, or, as Graham suggests in her quote, practice and the proficiency that rises from practice invites the perfection preferred.

In reality, not all design is better than the existing solutions; new design knowledge validates its value through stakeholder competency judgements. Depending on the newly designed outcome, the new design may compete successfully with the existing disciplinary practice, at times displacing it to become the new best practice, or it may fall short. Competency stakeholder validation introduces the many conditional variables often seen and unseen in the new product design process. Ultimately, how the new design competes in this stakeholder-based validation is the measure or metric of the new design's innovation.

Whilst new products tend to focus on solving a particular stakeholder problem, I have experienced that the success of the solution often depends on the definition and framing of the problem, as well as the integration of multiple value creators into the designed solution. This differentiation beyond the problem's form and function, provides multiple sources of advantage and unmet opportunity recognition for the practitioner-designer. Researching these additional points of differentiation is necessary in the new product marketplace, in which one must seek to not only solve the problem, but to do so in a way that results in multiple recognizable and sustainable competitive advantages.

4.2 Three Product Cases Creating Value and Advantage

4.2.1 Case One – Insta-Flow Dispenser Case

This case is the first patent of a design engineer seeking to overcome the problems of a two-component meter and mix dispensing technology. The particular focus of this product application was the improvement of a portable two-component polyurethane (PU) spray insulation foam kit. An inventor-entrepreneur named Bill Brooks previously created this technology. The Brooks invention had pioneered a new technology into the marketplace with his entrepreneurial start-up Insta-Foam Products. The kit was designed to be portable and could be utilised at a remote job site without the need for additional utilities or equipment to create the PU foam. The product mantra for use was a “Foam Machine in A Carton” (see Figure 4-1)

This item has been removed due to 3rd Party Copyright.
The unabridged version of the thesis can be found in the
Lanchester Library, Coventry University

Figure 4-1: Taken From Insta-Foam Products Sales Sheet (1985) – Depicting Three Kit Sizes

The Brooks kit was a breakthrough two-component polymer technology, but suffered from reliability issues that severely limited its use in the field. The failure of the system was dispenser blockage shortly after first use, resulting from the highly reactive nature of one of the material components. This reliability was an issue that users lived with for approximately ten years, as there was not alternative option in the marketplace. The company was well aware of the problem and diligently worked on a solution without any significant improvements for those years. In 1984, a competitor entered the marketplace with a much-improved dispenser, and the user-stakeholder expectations for performance changed radically, significantly raising the bar for the two-component kit business in the marketplace. (See Appendix, Case 1)

This new design by the competitor immediately shifted the dynamics of the marketplace in the 2004-05 timeframe; although Insta-Foam had a very strong brand and market distribution position, it was now seriously challenged. It was at this time that I had joined the company and was assigned the challenge of solving the dispenser reliability problem. The design and the development of the ultimate solution, which has now competed as the dominant technology in the marketplace for over 30 years, resulted from a very different approach to the problem than earlier attempts. As noted and detailed in the case history, the use of traditional engineering practices had fallen short of solving the problem and I was challenged to reframe the problem, seeking a new approach that would get to the root of the dispenser failure issues.

This case also reflects the designerly quest of a new product designer and developer, as all the existing engineering solutions were failing and the problem required new thinking. The case history details that, while the management directive was to improve the existing design, the solution required a radical departure from both the existing design and the project brief. Reflecting back, I had not followed my directive as stated. I also ran a parallel project of redesigning the existing design. Had I not expanded my design options I would have not invented the ultimate solution to the problem. I found that logically, when the existing knowledge falls short or is not viable in practice, what is required is a new knowledge thinking process to address the situation. This new thinking led to a solution that had alluded my predecessors for close to 10 years.

Completely immersed in this frustrating assignment, I was literally dreaming about this design problem at night. As I continued to attempt a workaround of the existing dispenser's design limitations, a creative inspiration evolved that eventually led to the new design. The problem was obvious in this case, yet the solution was elusive as the previous attempts to solve it focused on the symptoms of the problem and not the root cause. Having had a number of years' experience in other PU equipment problems, I first researched and analysed the problem and needs of the stakeholders, seeking the root cause. Having identified these technical constraints, I was able to bring new focus to the problem allowing me to reframe potential solutions.

Based on the functional performance needs I had identified, and drawing upon my experience in problem solving in this domain, I had a vision of a better way to create a new valving system for the dispenser that addressed the root causes of the

dispenser failures. Politically, I had a direct mandate to find a way to make the existing design perform, as it was the accepted belief that there was not a better way to redesign the valves after so many past failures. As I did not want to be insubordinate by disregarding my mandate, I continued to struggle with the current design at work, while I also developed my redesign in the evenings and on weekends, not giving in.

Reflectively, I believe that this design quest empowered me to achieve the eventual solution. In tacit knowledge practice, experience and trust of the design process combine intuitively to drive one toward the goal. For me the only logical explanation for this designerly quest is that perseverance and passion augments the proficiency arising from the actions of the design practice. Success in practice provides trust in the process based on experiences, rather than any form of explicit knowledge. Proficiency in design develops from repetition of this design quest.

4.2.2 Case Two - Anti-Crossover Nozzle Case

This second case builds on the first case study, further addressing the problem of the first case study of material backflow from the mixing nozzle into the dispenser's flow pathways. With the 1985 advent of the Insta-Flo Dispenser design (the Brown 437' design) discussed in the first case, the main performance issues with the dispenser had been solved. As happens in evolutionary development, once designed, the product if successful will continue to be used in more and more situations. As the use grows and more challenges appear pushing the product performance to its limits, new issues appear at the boundaries of function.

This rising bar of expectations is part of the new product design continuum as stakeholders' expectations continue to rise. Stakeholders often are immediately satisfied with a better offering at first, but they quickly adapt their expectations around the next best available product. Once the new Insta-Flo dispenser's performance improved, it allowed for wider spread usage of the kit for insulating, and the users continued to push the system to extremes. New users with less training became stakeholders.

The dispenser relied on disposable mixing nozzles provided with the kits, and frugal users did not want to purchase extra mixing nozzles, thus they would continue to use a nozzle even though the material inside was blocking the mixer and passageway. One continuing issue created by reusing a nozzle is that it clogged,

creating the possibility for a failure due to a forced material crossover created by activating with a clogged nozzle. The redesigned Brown 437' dispenser was still using the 20-year-old mixing nozzle design of the original dispenser. Forced crossover originates from backflow of mixed material into the material passageways of the dispenser; reacting material not able to exit the nozzle flows back into the dispenser as inexperienced users continually try to dispense foam with a clogged nozzle. I had recognised this as the final challenge in eliminating inexperienced-user-created failure of the kits. In a continuing effort to eliminate dispenser fouling and make the system fool proof, I sought to address this problem during a retooling of the existing nozzle. My quest was the elimination of unintentional or intentional crossover during usage.

As seen in US Pat. # 4,117,551 ([Brooks and Heinzel 1978](#)), Brooks attempted a nozzle redesign earlier to address this problem by utilizing a traditional engineering solution in 1978. During the mixing operation, if the operator were to activate the dispenser with a clogged nozzle, as they were prone to do, the forces from the reacting material in the nozzle can overcome the dispensing pressure of the components and reverse flow into the material supply paths of the dispenser. If this were to happen, the dispenser clogged with reacted material and was rendered inoperable. Whilst the spool valve invention of the first case solved many issues, this backflow problem was still possible in certain cases of misuse, especially with untrained users. Seeking to create a virtually fool proof system required addressing this issue, along with several other issues of the mixing nozzle.

Brooks approached the challenge by placing traditional mechanical check valves in the nozzle orifices in 1978, as shown in the patent drawing below (see Figure 4-2). This solution appeared logical from an air or fluid processing existing technology practice, but it failed to work with (PU) components, as the Isocyanate (A) component has a reactivity with moisture similar to that of super glue (cyanoacrylate). The Brooks check valves were an attempt that failed to work and scale for the application, and thus never commercialised.

The challenge of the PU component chemistry combined with the fact that the size of passages was so small that it was required that the ball and springs check valves be unrealistically small to function. Brooks also intended this nozzle to work with his updated dispenser flushing design of the 551' patent. The viability of incorporating a flushing system into the portable kit business was not feasible for the

application. The problem needed a new thinking that started with reframing the problem.

This item has been removed due to 3rd Party
Copyright. The unabridged version of the thesis
can be found in the Lanchester Library,
Coventry University

Figure 4-2: Patent Drawing of Nozzle Design Brooks and Heinzl 1978)

This case is an example of design arising out of the necessity to address a problem when the existing knowledge of practice fell short. The ultimate solution, built on an experienced knowledge of practice combined with a proficient knowledge of the design process, was a very simple and elegant application of a valving method seen in the human heart. I sought to address the nozzle backflow problem, eliminating any possibility of it occurring, by redesigning the nozzle. The redesign discussed in detail in the case history eliminated even intentional attempts to foul the dispenser, raising the performance bar once again in the marketplace. Today a very challenging meter, mixing, and dispensing technology used only by professionals in the 1980s is available to homeowners at all the building supply stores in the United States. The elimination of the dispensing problems through designing new knowledge solutions allowed the technology to spread beyond highly trained specialists to untrained consumer users, greatly expanding the market and business of the technology.

4.2.3 Case Three - Creation of the Bionic Wrench Case

The Bionic Wrench evolved from a desire in early 2000 to create a case study for the Differentiation by Design (DxD) process itself in the product design and consulting business that I had established in 1991. Differentiation by Design® is the tagline I coined to represent the process of creating business value and competitive advantage through new product design. Prior to establishing my own design business, I had over 10 years of design and business experience in highly competitive marketplaces. My engineering work evolved into design and engineering work and

eventually into management of products followed by management of companies. From this progression of responsibility, I learned tacitly that design gives one the best way to differentiate your offering amongst the competition in all the areas of a business; design in business was the best return on effort for creating competitive advantage in the commercial markets.

This DxD philosophy is a natural expansion of my design quest, and I integrated this philosophy into my management philosophy. Having had success working for others, I believed that I had a unique product design and invention ability and proficiency, which I could leverage as a new product design and development consultant. Having had significant industry success in several technologies and markets, I was able to attract clients in the industries that I knew well, including past employers and competitors. In circumstances where potential clients were aware of my work, selling my services was straightforward, but in situations where the prospect did not know my work, I found myself relying on patents to tell the story of my design work. Patents only go so far in telling a design and development story: I realised what I needed was a case study from concept to commercialization of this DxD strategy as a tangible example for prospects.

The need for a case creation employing the DxD process came from my experience selling design services to clients. As an independent new product design and development consultant, I was not only required to practice the design process for my clients, but to constantly look for new project opportunities to fill the design business pipeline. I had tacitly utilised a design process, building on the experiences of my past work and my designerly quest, to deliver the new product value and competitive advantages required to compete. This was as much a designerly strategy as a practice. In addition, I had concentrated on securing the commercial rights by also getting patents to protect the new product investments. The focus of my design strategy and practice evolved over time; early in my career, I focused on design as a problem solver, especially an inventive problem solver. As I matured and recognised commercial competitive needs, I realised that functional problem solving was only the beginning of a strategic process for exploring product advantage and viability.

One challenge I encountered when selling my design and consulting services was to expand my clientele beyond clients and technologies that were familiar with my services. Existing client relationships were often long term multiple projects, and new business could begin out of a lunch conversation. I had an established successful

history with clients, developing trust and respect from past successes. I delivered the new product competitive advantages in the marketplace that they sought and secured them with strong patents, and they came to rely on this practice. The one situation that occurs, as exhibited in the first two case studies, is that one's success in eliminating problems reduces the need for one's services, as that particular problem disappears. In a few relationships, because of my product design success, I was designing my way out of existing work, challenging me to seek other opportunities for new design and development work.

Selling my services to prospects who did not have experience with my work, or had not competed with products I had designed, was challenging. It was often necessary to persuade sceptical prospects that an outside person could deliver the new product results and competitive advantages they were seeking. Often companies had their own employees, and more often than not, they had negative new product development experiences. When selling my services, I could show them my patents and share narratives of my work that were not confidential, but this did not completely satisfy my needs of communicating the DxD process. Complicating things, I had considerable success in the body of my past work, the data was there, but I had to sign a confidentiality agreement with my clients that often stipulated that I could not disclose the nature or activities of my consulting relationship with them. I found it challenging to discuss the specific details of my design services with prospects beyond patents, which were in the public domain with my name on them.

There were products in the market that I had designed, but that were not recognised publicly as my work, even when they received industry awards. These awards went to my clients as owners and public face of the technology. Although my clients paid me well and did recognise my work with internal awards from their organisations, my recognition as a designer, as well as my ability to grow my design business, suffered by this lack of public recognition for this creative process. Consequently, I desired to create a new product, with my own funding, from concept to commercialization, that would serve as a case study of my differentiation by design process. Simply put, I wanted a design story that I could use to sell and market my DxD services.

It took a tragic event to push me to pursue this new case study design quest. I was in Las Vegas for a trade show the day before September 11, 2001. Part of my reason for attending the show was to meet with a prospective client on a large new

project. This was a common way to develop business, and I had secured a meeting with a past client to discuss a new product advancement that I envisioned for his business. We met, and he was interested in the proposal; we agreed to meet again the next day to formalise the project. The next morning, the World Trade Center in Manhattan, New York, was attacked. Obviously, our meeting cancelled and the further discussion postponed. It was during the long days of this week while still in Vegas waiting for the airports to open, with all the craziness of the 9/11 situation, that I committed to pursue that in-house new product design opportunity. Subsequently, I started putting some serious efforts into identifying a real problem to solve, one that had the commercial viability for both technical and business start-up success, and that explicitly demonstrated the DxD process.

One aspect of this case compared to the first two cases is that it is much easier to begin a design project like this with a real world problem that is in dire need of a solution. For Case 3, I set myself on a design quest with turned out to be the Bionic Wrench case history detailed in the appendix. This case, unlike the first two cases, required me to first identify a real problem, in a viable marketplace, that warranted the investment of time and effort for this case development. New product opportunities with market viability built into them are elusive but critical for commercial success. Far too often, newly designed products are solutions looking for a real market to sustain the effort. I often tell students that building a commercial enterprise from this strategy is like pushing a rope up a hill. Identifying a real problem is crucial for this type of design project; it is also a significant design research challenge to find the right one.

These real-world problems must be market-driven needs, existing solutions that have knowledge gaps where stakeholders are searching for a solution. Having customers seeking a better way and willing to pay for a better solution eliminates the need for an entrepreneurial start-up to pioneer a completely new market. There are those projects on the other end of the spectrum also, with tremendous market viability if solved, but so technically challenging they are seemingly impossible for new product development projects. The right project for this case had baked-in market viability and a technical white space for execution of a new knowledge solution protectable by intellectual property. These just do not appear; they must be researched and uncovered, and I maintain that this is as much a design process as a business process, or the skill of a proficient marketer-designer. The narrative in Case History 3

is one such example of a large market (the hand tool market), describing in detail the journey of creating the Bionic Wrench and the insights and reflections of the journey.

4.3 New Product Design Evolving Themes, Practice, Teaching, and Research

The autobiographic reflection on personal design practice offers unique challenges and insights into the process that do not typically arise when conducting other methods of product design research. The first-person knowledge of data and facts arising from competitive market situations is typically hard to access. The nature of the competitive dynamics, among other factors, encourages businesses to restrict access to this knowledge. Unique access to actual experiences leverages this unique practitioner-researcher relationship in support of the data and insights arising from the past practice. In addition, it makes a case for the relevance of an autobiographic reflective practice, when objective quantifiable evidence is available in support of the qualitative data and information relied upon.

In addition to my design practice, my I am now starting my tenth year of teaching Design, and creating and teaching this course has provided data for this research. I developed and continually evolved a Masters-level design course entitled “[Differentiating by Design](#)” at Northwestern University. Teaching provided a bridge from the tacit knowledge of practice where I learned the lessons, to the classroom where I have taught the lessons, and now to this thesis where I am researching and seeking to explain these lessons as new design process theory. This progression from the tacit knowledge-based design practice now to the academic teaching of this practice has proven to be successful in this particular experience, and the student class evaluations have reflected this.

Being invited to create a Masters-level academic course based on the Differentiation by Design process 10 years ago challenged me at that time to reflect on the tacit lesson of my experiences and to organise them into a cohesive pedagogy. Over the period of a year, I worked with an experienced faculty member to develop the 10-week course into a sequence of design lessons. The focus of the course was product design from a business value creation perspective, beyond traditional form and function, for students learning the Human Centred Design process to gain the knowledge of how this process integrates into the organizations they would be working for after graduation.

My course reflected my professional work for the creation of competitive advantage through strategic differentiation by design. The readings and lessons bridged design and business, focusing on those design-based value-creating opportunities beyond the traditional form and function aspects of a product design and development. This course development was a reflection and synthesis of my consulting practice in industry, guided by an experienced teaching and research professor Ed Colgate who created and directed this new program at Northwestern.

Building on this course success, and seeking to create an academically rigorous treatment of this design process, I had a goal of writing a product design book integrating the lessons of the DxD process. Researching the book market and requirements for a crossover book that practitioners as well as students could use, I discovered that course texts required academically researched content. Thus, this doctoral research of practice became the next step in this journey, seeking to provide academic rigour and theory to the narrative lessons in the book. Arising from practice, this course has provided a basis for an ongoing analysis (see Figure 4-3), developed from my years of design practice in the marketplace, and updated yearly from student feedback and my reflections from the course experience.

4.3.1 Course Themes – Heuristics of a Reflective Design Practice



Figure 4-3 Differentiation by Design Course Thematic Analysis Arising from Reflective Practice

4.3.2 Supporting Data from Informant Interviews – Thematic Analysis

In further support of my reflections, I conducted informant interviews. The interview questions focused on the subject's role in the particular case related to his experience, as secondary sources of data to inform the primary data sources. I sought emerging themes from the interviews.

Interviews in Support of the Reflections on the Case Studies

Roger Fisher – Past President of Insta-Foam Products - Roger was the President of Insta-Foam Products, later The Antenna Company. Roger was a participant in the process of the development of the Insta-Flo dispenser in 1985. Roger has historical perspective on the preceding technology that the Insta-Flo dispenser replaced. Roger also has development knowledge directly related to the repeated attempts to redesign the predecessor to the Insta-Flo dispenser. Roger has direct knowledge about the establishment of the project that created the Insta-Flo dispenser.

Purpose of Interview: Support the historical reflections leading up to the design, development, and discovery of the Insta-Flo dispenser, as well as provide new reflections on the development and discovery of the Insta-Flo dispenser.

Jess Lukancik – Owner of KLJ Machine Shop - Jess was the founder and owner of KLJ Machine, a machine shop located in Joliet, IL, that I utilised to build prototypes of the Insta-Flo Dispenser, Anti X Over Nozzle, and Bionic Wrench. Jess has first-hand knowledge of the development of all three products in the case studies; my relationship with Jess spanned 20 years through his retirement in 2005.

Purpose of Interview: Support the reflections for the development and discovery of the Insta Flo dispenser and the reflections for the development and discovery of the Anti X Over nozzle, as well as the reflections for the development and discovery of the Bionic Wrench (all three case studies).

Randy Peterson Interview – Past President of Flexible Products - Randy was a long-time employee of the Insta-Foam, Flexible Products, and eventually Dow Chemical ownership of the technology created in cases 1 & 2. Randy eventually rose from salesperson (in 1985) for Insta-Foam to President of Flexible Products Co. and Vice President of Dow Chemical after Dow's acquisition of Flexible Products.

Purpose of Interview: Support the reflections for the development and discovery of the Insta-Flo dispenser, and support the reflections for the development and discovery of the Anti X Over nozzle.

Bill Yeomans Interview – President of Yeomans and Associates - Bill Yeoman was an employee of Insta-Foam Products, who transitioned into an independent representative for Flexible Products and later Dow Chemical Company. Bill had direct market experience with both the Insta-Flo dispenser and Anti X Over nozzle cases from the marketplace perspective.

Purpose of Interview: Support the reflections for the marketplace success of the Insta-Flo dispenser, as well as support the reflections for the marketplace success of the Anti X Over nozzle.

Raymond Cherfane Interview – President of Cherfane Technologies - Raymond was hired as an engineering manager by Flexible Products Corp. in the early 1990s. Raymond also has considerable design insights and experience in the New Product Design and Development process, having started his own business in New Product Design and Development upon leaving Flexible Products in the late 1990s.

Purpose of Interview: Establish the facts supporting the design, development, and discovery of the Insta-Flo dispenser.

Ross Wilson Interview – Engineer at Flexible Products Co. - Ross was a design engineer at Flexible Products Company in 1990; he was also an observer in the process of the development of the Anti X Over nozzle.

Purpose of Interview: Establish the facts supporting the outcome of the design, development, and discovery of the Insta-Flo dispenser, although the original dispenser was designed five years prior to his arriving at Flexible Products Co. In addition, Ross had first-hand knowledge of the development of the Anti X Over nozzle of case 2.

Each interview was transcribed from the recordings into a written Word format, and the interviews were combined into a master document and coded utilizing a Grounded Theory coding process as discussed in Methodology section 3.9, and seen diagrammatically in Figure 3-2.

For coding, I employed qualitative coding software (QDA Miner) to analyse the data. A Grounded Theory approach to thematic coding and categorization of the qualitative interview transcripts identified the four themes below (see Table 4-1). The first open codes produced a wide range of topics. This first coding was analysed for common themes. These were analysed in relation to the questions and again coded, reducing the themes into related categories. Once the themes that the data were coded into were identified, a third round of coding developed the top emerging themes from the interviews, as summarised below. “Count” represents the number of instances of the code appearing in the interviews, and “percentage” represents the code appearance as a percentage relative to the total coded data set. “Percent of Cases” acknowledges that all four code descriptions were present in each interview data set.

Top Emerging Themes From The Interview Process				
Code	Description	Count	%Codes	%Cases
PROBLEM FINDING Framing / Re-framing	Researching, reframing and seeking the root causes of the problems that need to be solved.	267	34.70%	100.00%
NEED FINDING Stakeholders Across the Consumption Chain	Seeking to define the needs of the problem and stakeholders, seeking the Unmet, Under-met and Unarticulated needs.	132	17.10%	100.00%
WHITE SPACE FINDING Differentiation	Strategically driving the design differentiation into the areas with little or no competition in both the technical and the marketing competitive spaces.	70	9.10%	100.00%
DIFFERENTIATION SOLUTIONS	Discussions of how design created new value and competitive advantage that could be protected by patents, trademarks or copyrights.	145	18.80%	100.00%

Table 4-1: Summary of Emergent Themes from Interviews

4.4 Heuristic Process Themes for New Product Design

Designing, by nature, seeks the “preferred state” objective of Simon’s definition, “[who devises courses of action aimed at changing existing situations into preferred ones](#)” (Simon 1996: 111). This research agrees with Simon’s process focus of creating preferred objectives in the context of new product design. In the CAM framework provided in Chapter 5, I explain this knowledge framework as a practice-design-competence knowledge in flux dynamic, a model at the centre of the new product knowledge creation process. Building on Kuhn’s theory of paradigm change, judged by the paradigm stakeholders in his work, I am adopting a similar condition to judge the value of new product design. Similarly, for new products, the context and

stakeholders of the respective market paradigm are necessary for validating new knowledge propositions in new product paradigms. Design that achieves this stakeholder preference over existing solutions is the metric of value creation and competitive advantage.

On reflection of my past design challenges, I have articulated heuristics (a rule of thumb arising out of a well-practiced methodology) that I have found fundamentally consistent in this new value creation. The intent of representing the following heuristic themes of this research is not to define a formulaic process of design, a sequenced process that will work the same way for all projects. Formulaic methods are by nature inflexible applications relying on established rules used in a logical order. An example would be an arithmetic process of calculating the stress or load on a bridge. Formulaic processes are paradigm confirming by nature; design processes must be paradigm changing by nature, requiring flexibility and adaptability to the new knowledge creation challenge at hand. Design creates the new rules where the existing rules fall short in practice.

Instead, the purpose is to share the governing heuristics of how designers create new-use, product value and competitive advantage in the marketplace. Design heuristic models are not new to design; there are examples in other design practices. These heuristic themes arose in this study: the constituent methods and skills for researching problems, identifying the needs, analysing the data for white space opportunities, and synthesizing the preferred new knowledge with a competitive focus. Skill or proficiency in addressing knowledge gaps in practice is the essence of design when compared to practice.

4.4.1 Design is an Innate Human Exploratory Research Quest

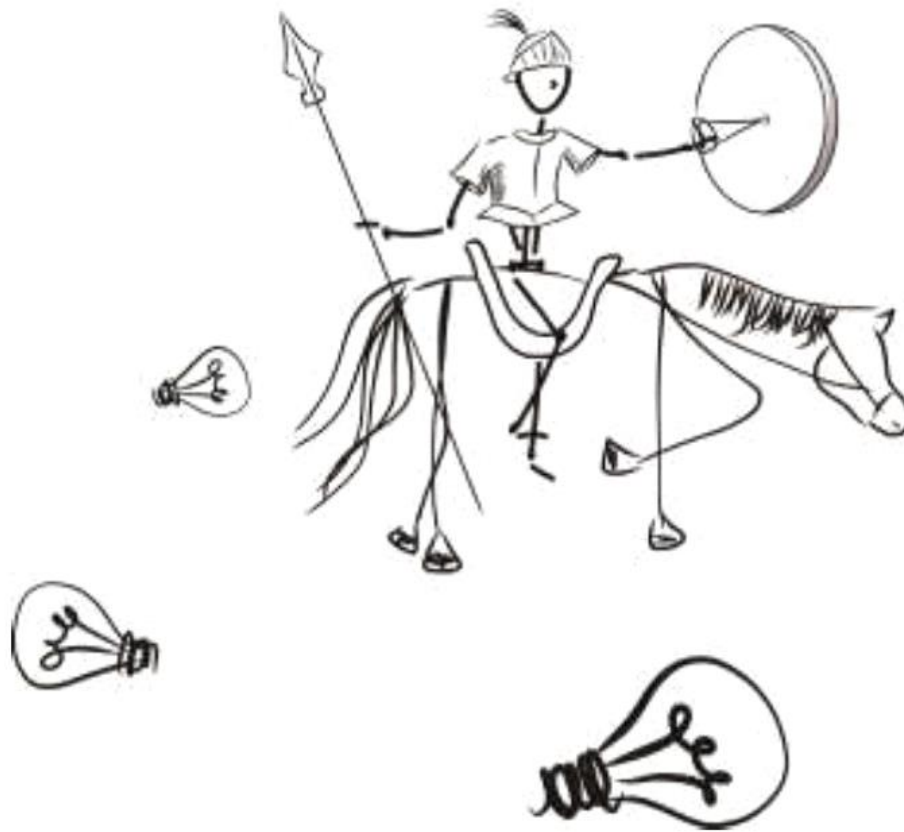


Figure 4-4 Designer on an Explorative Creative Quest for New Knowledge in Practice

A new product designer is a practitioner, in any discipline, who pursues new knowledge of the discipline in the quest of creating new value and competitive advantage in his practice. This drive often arises when the existing knowledge of practice falls short of meeting the objectives of the practitioner. The quest begins when existing knowledge cannot adequately solve the challenge; competition drives this quest in an evolutionary equivalent of natural selection, expressing itself in the marketplace for new products and services. This designerly quest can be in response to any number of situations, for example when a competitor enters the marketplace with their own new product, raising the competitive expectations of stakeholders, or the quest can be part of a strategic process of proactively creating competitive advantage in an effort to stay ahead of the competition. Strategically this new product design practice must seek protectable advantaged differentiation that can sustain the commercial viability of the business. Proficiency in design develops from this designerly human quest, as the practitioner's designerly skills also evolve.

4.4.2 Designerly Enquiry is a Competitory Dialectic Synthesis and Reflection

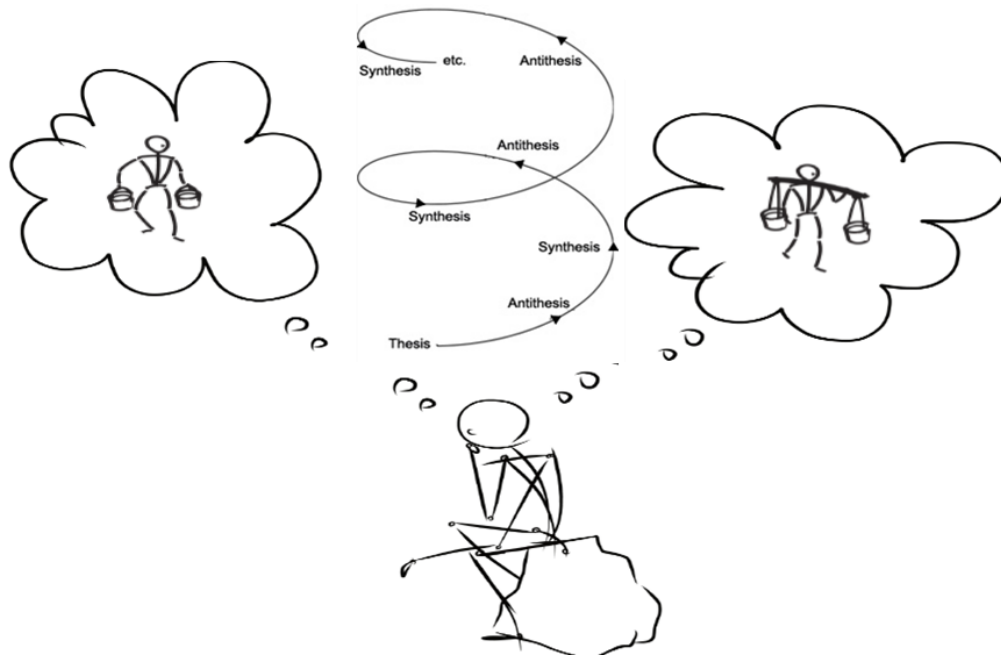


Figure 4-5 Designer in Competitory Reflection in Action - a Dialectic Mental Modelling Process

The designerly creative quest for new product design requires focus for the identification of competitively advantaged differentiators. As Schön articulated, this is reflection in or on actions in practice. It begins with researching the existing knowledge state and stakeholder preferences and expectations, providing the starting point for a dialect modelling and synthesis of advantaged propositions. How new propositional knowledge competes with the existing knowledge solution is the metric of this creative quest. The designerly methodology of research, analysis, and synthesis, practiced as a rigorous and evidence-based methodology, aspires be the qualitative rival to the quantitative scientific method. Seeking alone is insufficient; disciplinary rigour and methodology are necessary.

Although different from the scientific form of enquiry in that it is qualitative, design enquiry seeks the quantitative certainty that the scientific method of enquiry achieves. It is the new propositional knowledge that arises from reflecting on the existing knowledge benchmarks and creativity stimulated by the unmet needs of the stakeholders that brings focus to the creative thought process. The new knowledge synthesis is the result of a reflection in action by the designer as he mentally models the potential new knowledge in the synthesis and reflective validation process.

4.4.3 Competitive Evolution Drives the White Space Quest for New Knowledge

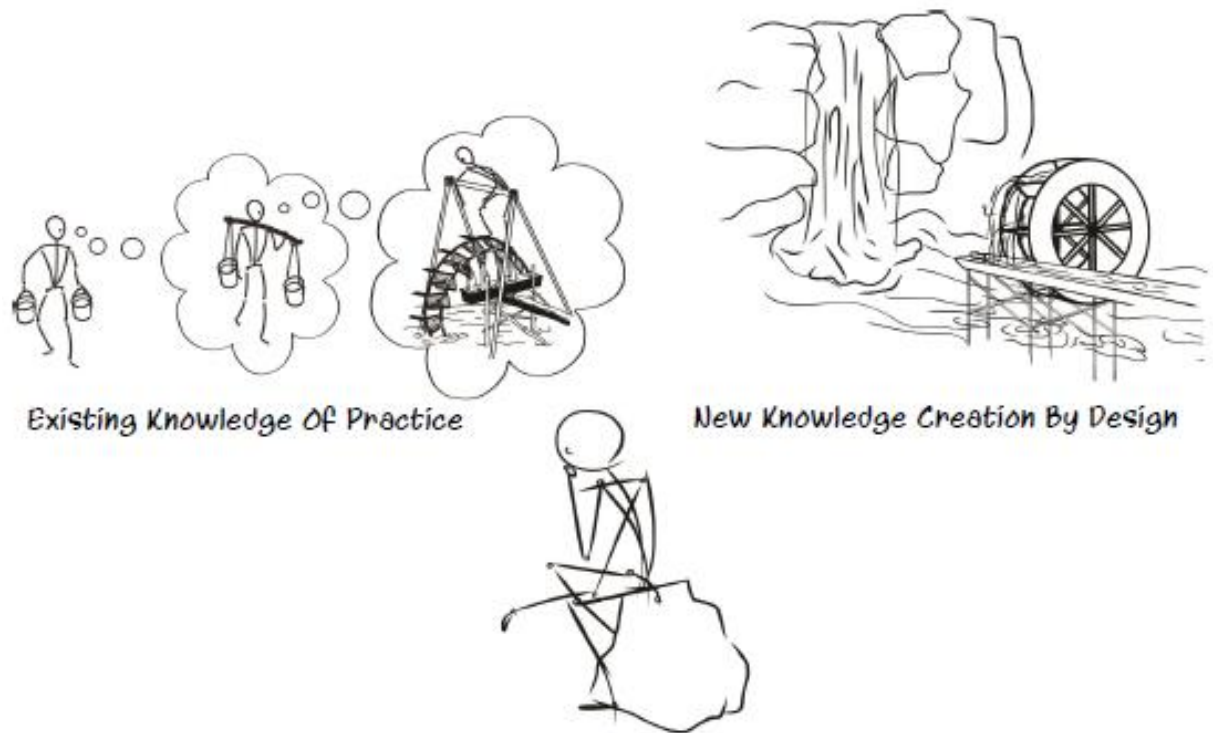


Figure 4-6 Designer Seeking the Knowledge Gaps and Mentally Model the Possibilities

Addressing the question of when I was practicing engineering and when I was designing in the new product development practice, I have brought focus to the knowledge gap in practice as a state of disciplinary practice. Problem finding, need finding, and benchmarking research provide the information through systematic enquiry of the existing paradigm knowledge. The designer first explores and documents the existing knowledge situation, providing a contextual reference and benchmarking for new knowledge white space opportunities to compete with the existing knowledge in practice.

Marketplace dynamics drive this competitive evolution for the creation of new products to compete with existing products in the marketplace. Designers seeking advantages must strategically look for new value-creating opportunities. Addressing these unexplored knowledge gap opportunities brings focus to a strategic plan for change, as logically there is little chance beyond luck to land in a new knowledge space without knowing the existing knowledge space boundaries.

4.4.4 Stakeholder Expectations Continue to Rise in a Competitive Environment

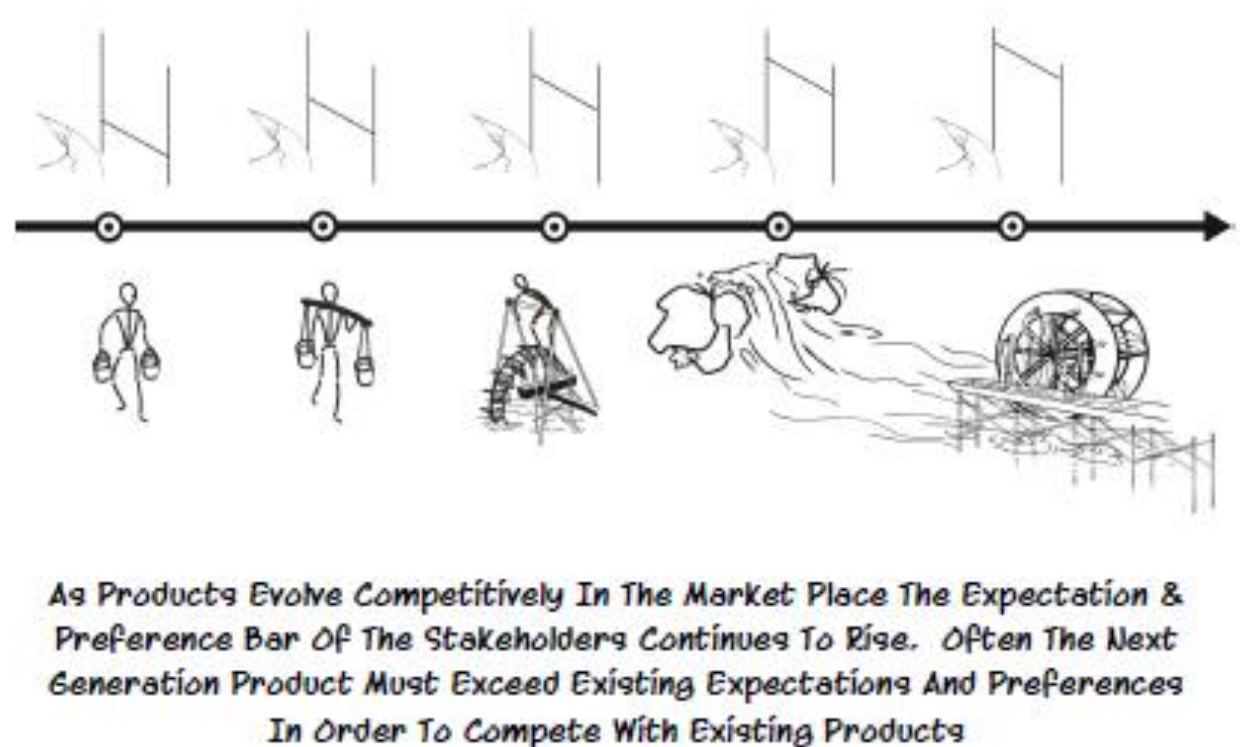


Figure 4-7 Stakeholders Expectation Benchmarks Continuously Rise in New Product Design

Designerly Competitive Benchmarking – Researching the historical product evolution and the associated stakeholder benchmarks can provide insights into trends, competitive responses, and potential strategies for the next raising of the bar. Through the identification of the stakeholder expectations of the existing solutions, the designer can create the metrics for establishing the existing and new needs of the stakeholders. This is a critical research phase of the design cycle. Stakeholders act as judges of value creation.

Stakeholder preferences will determine whether the newly designed product provides sufficient advantage over existing solutions. Stakeholders have endowed relationships with existing solutions; the new solution must have sufficient advantage to drive the stakeholders to change. These new value creators can arise throughout the consumption chain, and with multiple stakeholders.

4.4.5 Opportunity Spaces (White Spaces) Exist Throughout the Product Experience

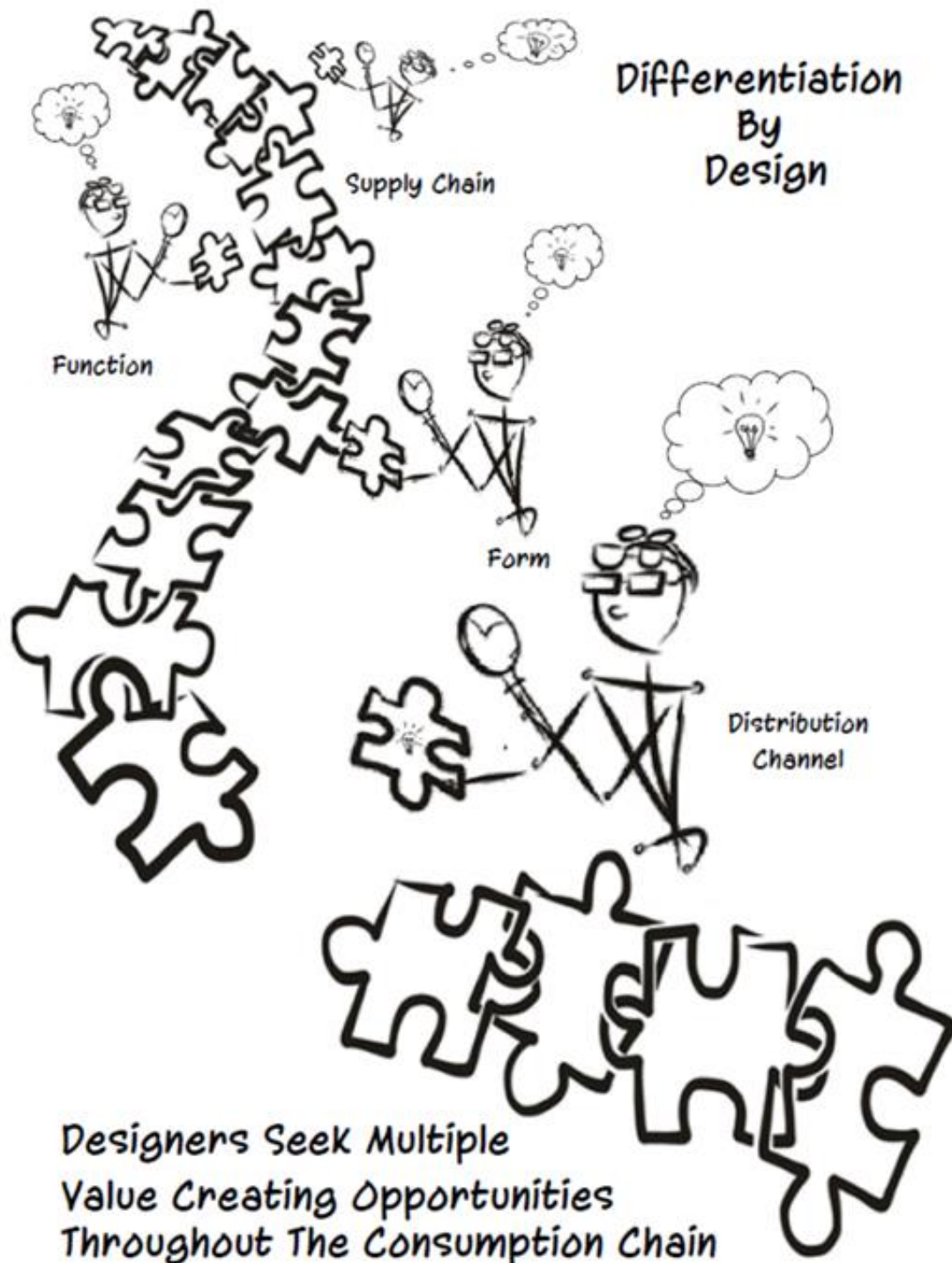


Figure 4-8 Designers Seeking Multiple White Space Value Creating Opportunities

Designerly enquiry searches, beyond form and function, at the multiple white space opportunities throughout the total product or experience, identifying opportunities for differentiation. Differentiating across these multiple points allows a designer the best chance of successfully creating commercial new product advantage.

4.4.6 Bringing Strategic Focus to Unmet, Undermet, and Unarticulated Needs

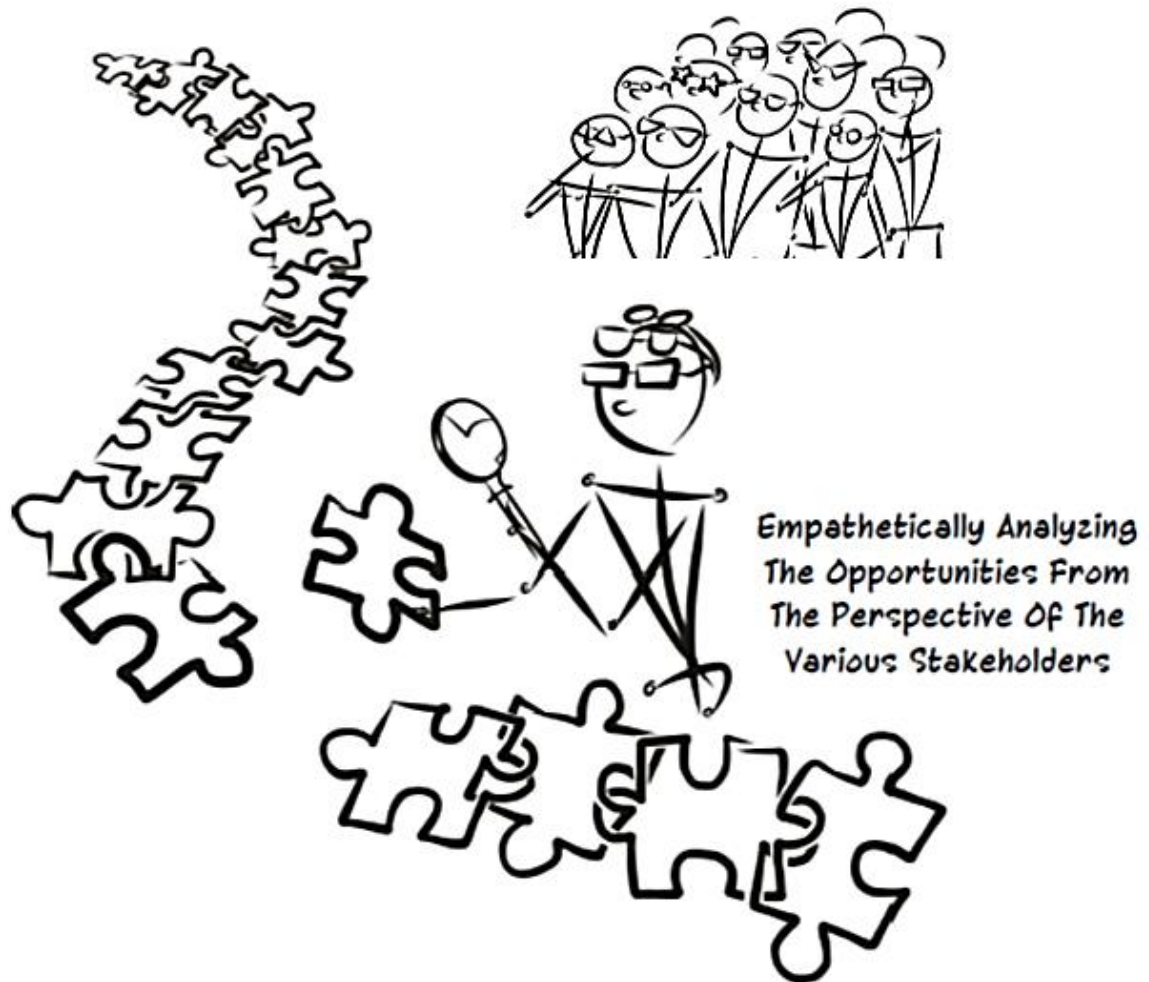


Figure 4-9 Seeking Unmet Needs Brings Focus to Potential New Value Creation

While need finding is a critical analysis of how stakeholders will judge your design, the goal of bringing focus to unmet and undefined needs that create value is critical. Not all needs have the potential to equally contribute to the commercial viability of the new product offering. Analysing the needs of all stakeholders and ranking those needs based on their ability to contribute to commercial viability brings a disciplined differentiating focus for the design process when seeking to create new product competitive advantages.

This analysis can determine the needs according to the following categories:

- Non-negotiable needs - standards and industry specifications.
- Minimum viable product needs – stakeholders' minimum expectations, often existing solutions evolved market performance metrics.
- Unmet needs that can create value - often identified by the gap between the existing knowledge and new knowledge solutions. This is where the designer can bring the most impact, and the best risk-reward effort pays off for the design process. Analysis is required to bring focus to these needs.

4.4.7 New Product Value Creation Requires Empathic Framing and Re-Framing

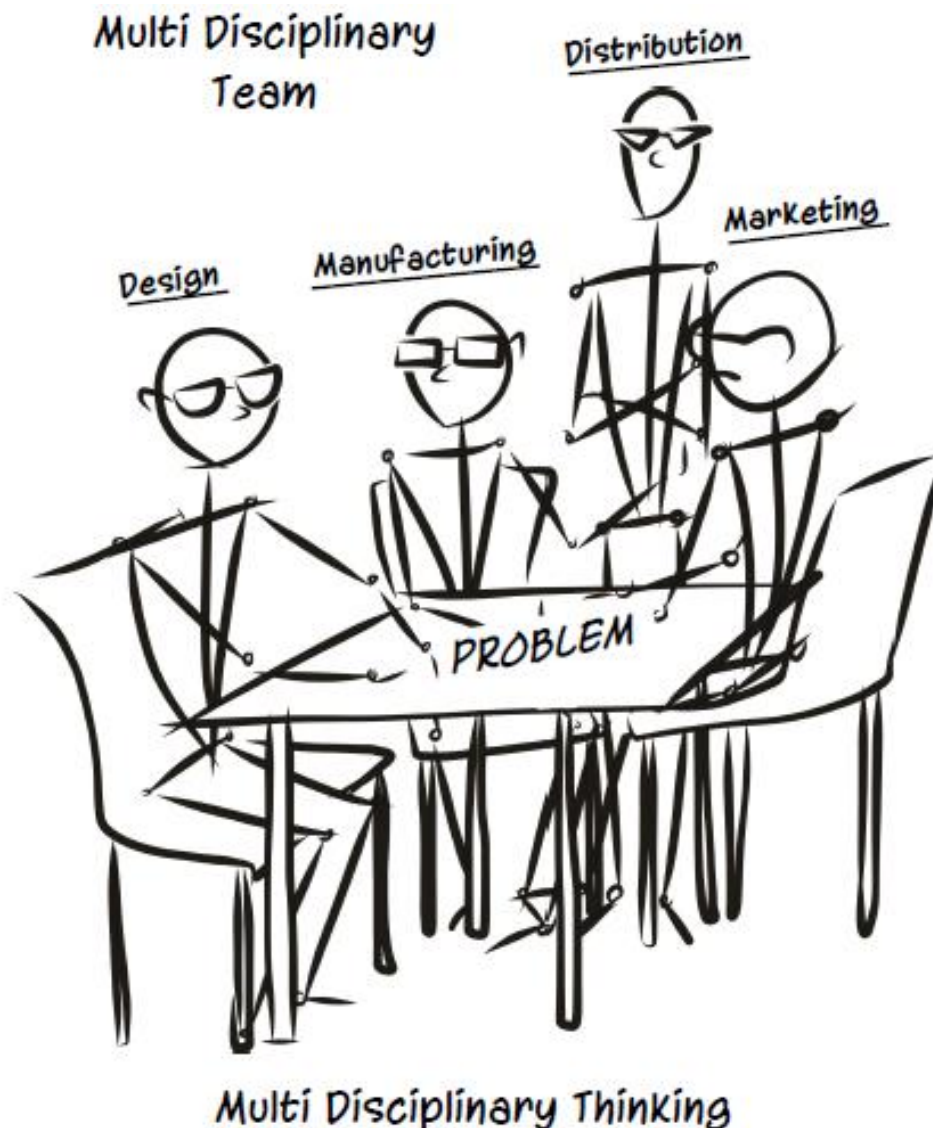


Figure 4-10 Designers Must View Problems From Multiple Internal Stakeholder Perspectives

New product design and development requires a multi-disciplinary thinking approach for research, analysis, synthesis, and validation of the new product knowledge iteratively throughout the process. Empathically, the designer must seek to see the challenge through the eyes of all the stakeholders, both internal and external, leading the multidisciplinary team in the design process. White spaces can appear anywhere in the product experience, and the perspectives of all stakeholders can inform the design process from an experienced lens. Leading this process, designers benchmark the value metrics from both internal and external stakeholders from their respective needs and perspectives.

4.4.8 Stakeholders Have a Bias for those Experiences They Know and Trust

Endowed Relationships With Past Experiences Raises the Bar For The New Product Entrants

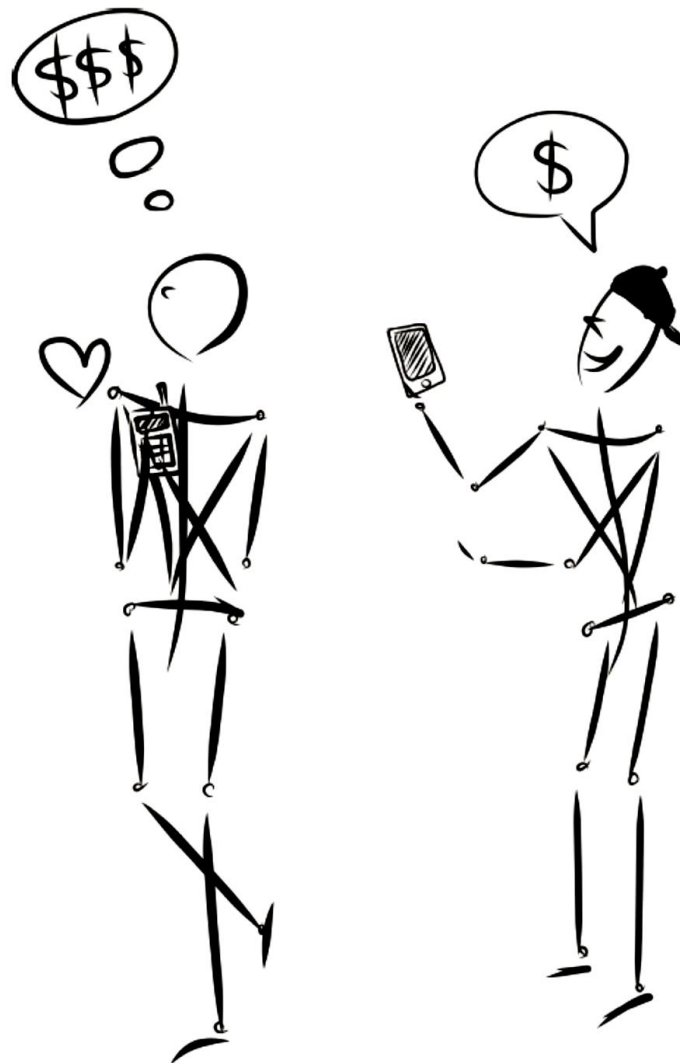


Figure 4-11 Designer's Focus on Attractive Value Propositions to Attract Customers

Form and function often are the primary focus of new product design challenges; although they are not the only aspects of the product experience that influence the creation of new competitive advantages. Understanding value creators beyond form and function through need-finding research is critical for commercial viability. Researching economic and behavioural benchmarks of the stakeholders and the analysis of their competitive relationships to one another identifies those needs most important to the marketplace stakeholders. Often, existing endowed product preferences anchor the behaviour. Simply improving on an existing product is often insufficient; you must convincingly compete for a new product entrant to succeed.

4.4.9 Design Enquiry is a Qualitative Method on par with the Scientific Method

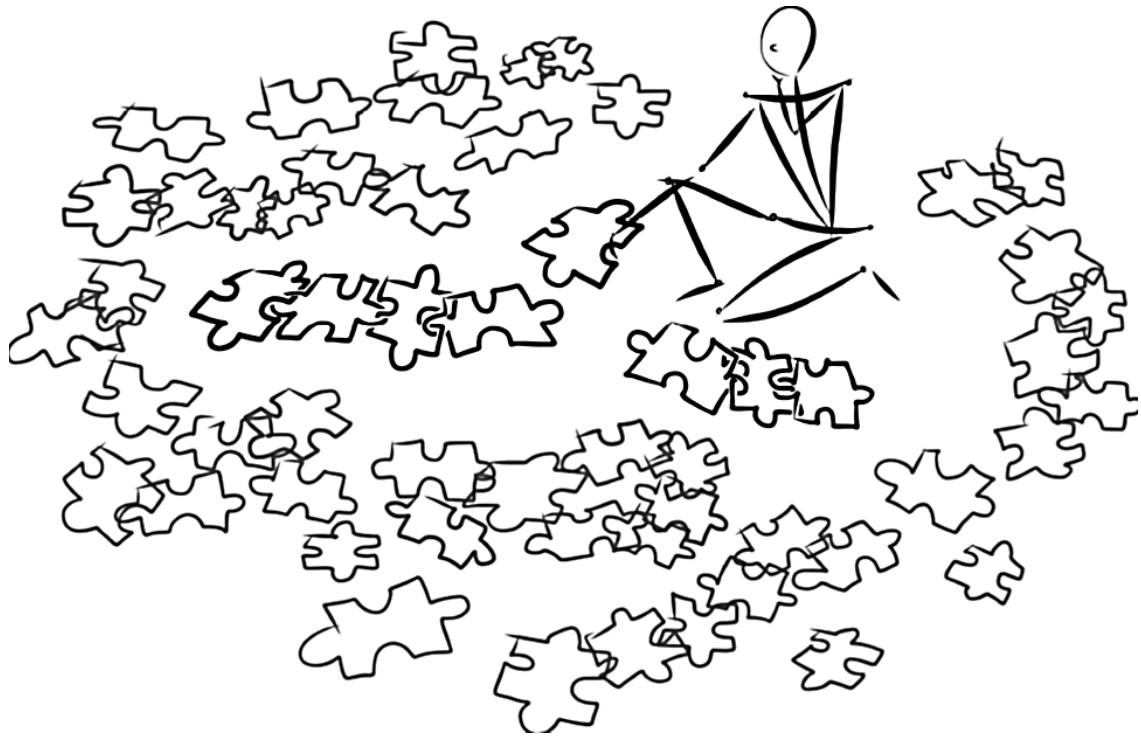


Figure 4-12 Strategically Viable Designery Execution as a Rigorous Systematic Process

Dynamics of the New Product Design and Development Process:

Research (seeking)

- Problem exploration, framing and definition
- Identification of internal and external stakeholders
- Need finding of stakeholder preferences beyond form and function
- Benchmarking of the competitive conditions for success

Analysis (conceiving)

- Identifying the opportunities (knowledge gaps)
- Bringing focus to the new value creation white space opportunities
- Developing the competitive design strategy that creates value
- Developing design requirements to guide the development steps

Synthesis (creating)

- Developing the differentiation strategy for creating advantage
- Creating mock-ups and prototypes to evolve the differentiators
- Stakeholder centred design interactions and iterations
- Create multiple competitive opportunities for competitive advantage

Validation (competing)

- Confirmation that the new knowledge propositions create advantage
- Implement the competitive advantages into a viable business model

Rigour (protocol validity and certainty)

- Evidence-based reasoning and designery valid methodology
- Design as a discipline provides proficient practitioners, leaders and teachers of this team-based, multi-disciplinary process

4.5 Research Heuristics

4.5.1 Bring a Root Cause Focus to the Problem Finding and Framing Challenge

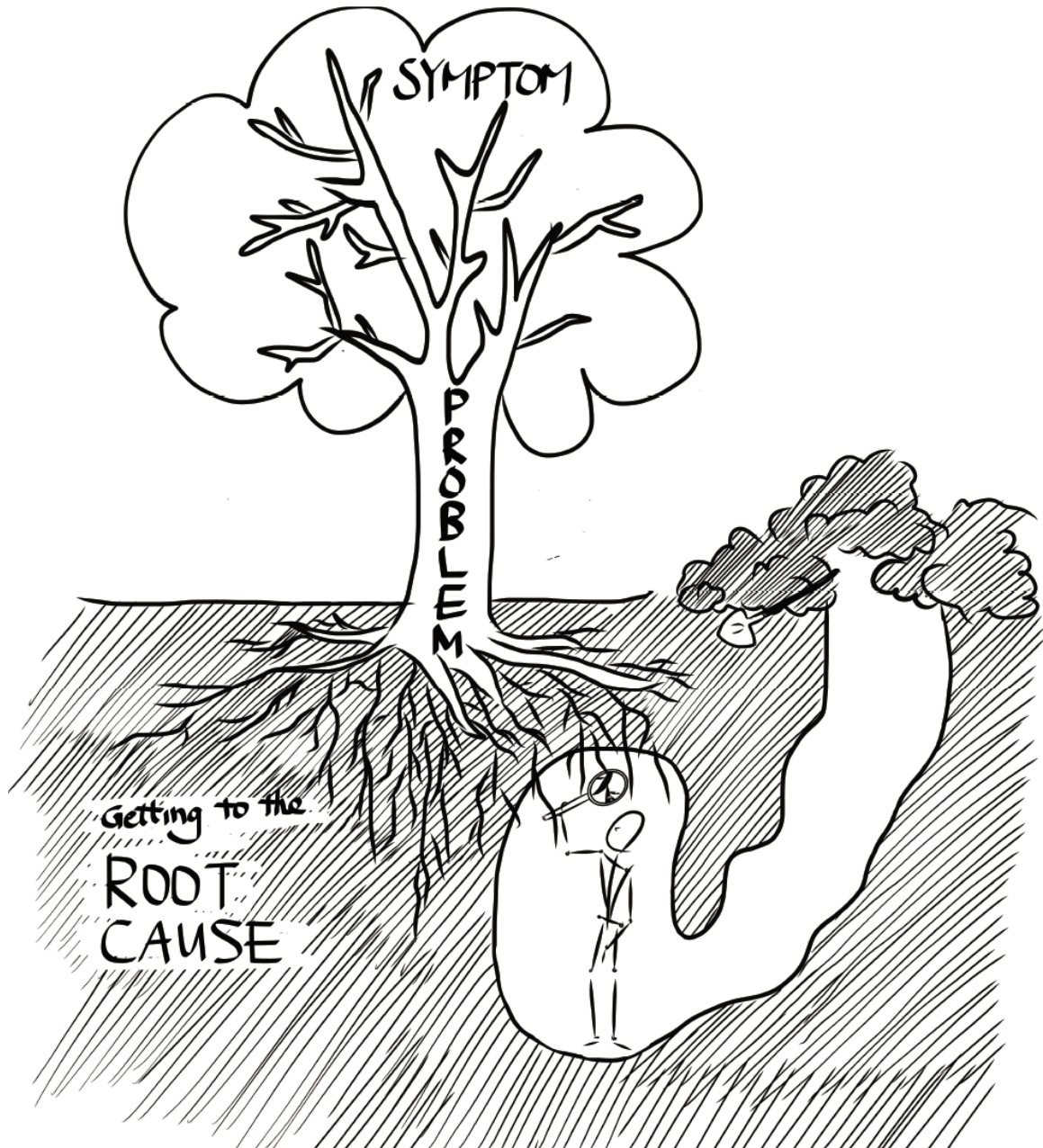


Figure 4-13 Can You Identify the Root Cause of the Problem, or Only the Symptoms?

Oftentimes, new product research efforts address the symptoms of a problem. However, the best solutions address the root of the problem. Visual or obvious problems can be seen easily, but when the problems are behaviour-based the root cause becomes more challenging to identify. Many solutions never address the root cause, as it can often be allusive or undiscoverable. Simply recognizing that you can discover the root cause can focus your problem finding, improving the design process.

4.5.2 Existing Market Benchmarks Provide the Competitory Reference for Research

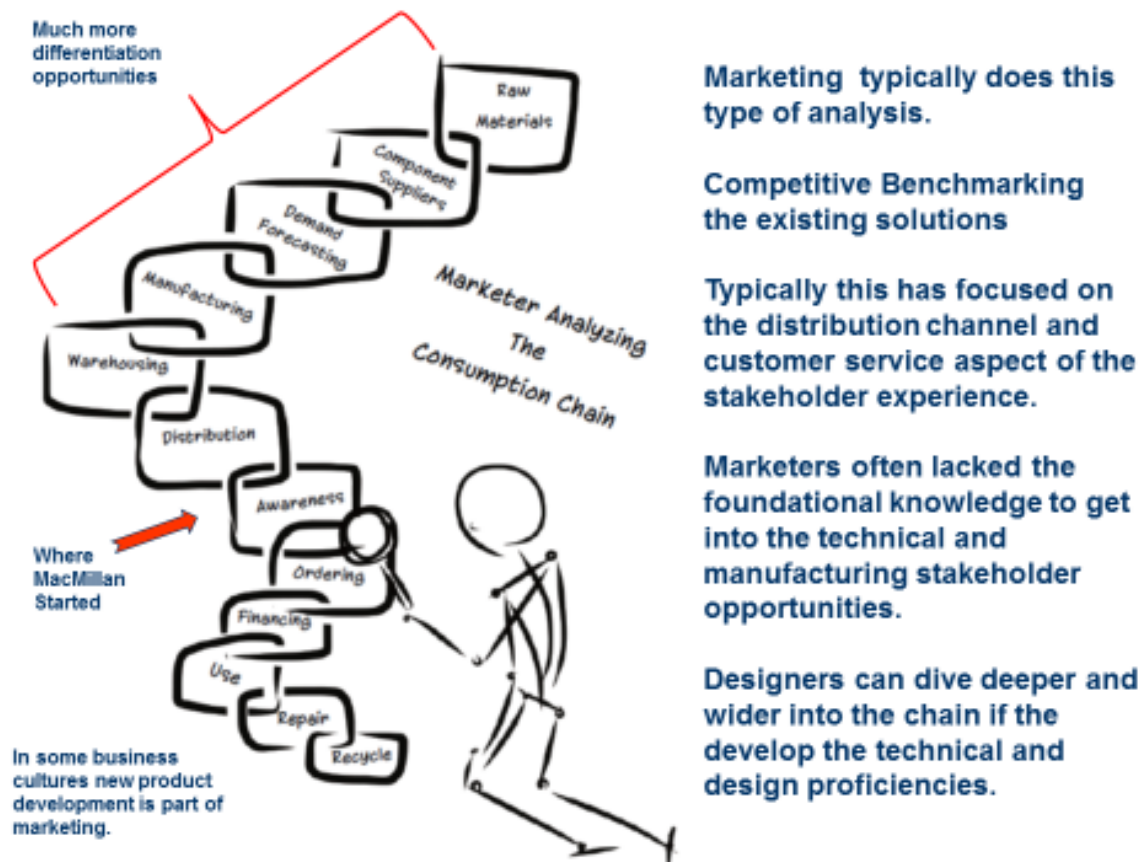


Figure 4-14 Research Beyond Traditional Marketing Research of Consumption Chain

Marketers have traditionally mapped the existing product-solution pathway to identify the journey steps of the existing and new product experience (Macmillan and McGrath 1997). Building off this methodology, designers similarly use this Journey Mapping approach to identify both internal and external key stakeholders' expectations in the product's life from raw materials, production, supply chain, distribution, channel, business model, and end of life. This consumption chain journey mapping acts as the existing knowledge reference to organise the design challenge.

Mapping the Chain from start to finish and analysing the stakeholders' experience from the initial need to the termination of the experience establishes the reference data needed to strategically identify all of the stakeholders that are involved with the product experience. Further analysing the needs, the designer can address often-unseen opportunities for differentiation that appear. Opportunities evolve from this need finding to bring focus for value creation and differentiation opportunities to create new value and competitive advantage in the product design process.

4.5.3 Competitory Economic Benchmarks Provide Judgement Metrics to Research



Figure 4-15 The Design Must Also Analyse the Value Judgement Benchmarks of Stakeholders

Designers must research and diagnose the existing behavioural economic benchmarks, establishing what a new, more competitive solution would look like. This dialectic modelling is a key element of creating a viable new product design strategy. Commercial viability is an essential component for this synthesis; new products that cannot sell and sustain themselves in the marketplace miss the opportunity to become viable new products. Commercial viability is a necessity for new product design, and research of the contributing factors that determine commercial viability is a significant challenge and component of the upfront new product design research. Rushing to establish project requirements without this research undermines the designer's ability to identify and address these value-creating opportunities.

4.5.4 Both Internal and External Stakeholders Influence the Design Research

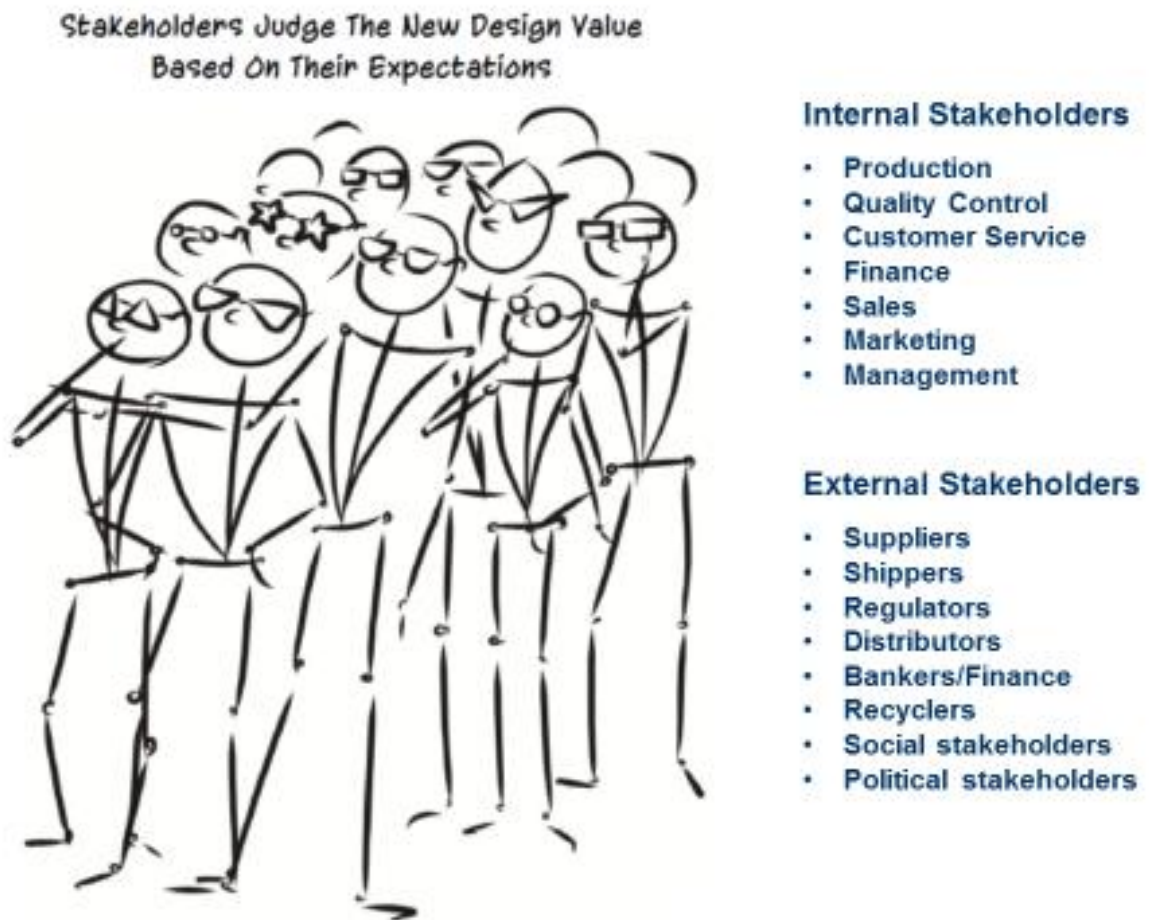


Figure 4-16 Stakeholders are Both Internal and External Participants and Judges of Success

Only focusing on the external stakeholders such as users and purchasers when researching can be a trap and lead to a failure in the product launch; quite often, internal stakeholders have a direct bearing on the new product success. For example, failing to engage the external supply chain or internal manufacturing stakeholders early in the process can easily result in a difficult or impossible production challenge at start-up.

Similarly, there are also considerable behavioural drivers that internal stakeholders have that can assist your development or impede it. Stakeholders have different needs based on their situations, and designers must empathically identify those needs. Not all stakeholder needs are equal; the designer must analyse the needs to identify and bring focus to those that will create the most value. Some needs are non-negotiable constraints, and other needs can be sources of new value creation.

4.5.5 Need Finding of Functional Drivers Often Provide Product Basing Opportunities

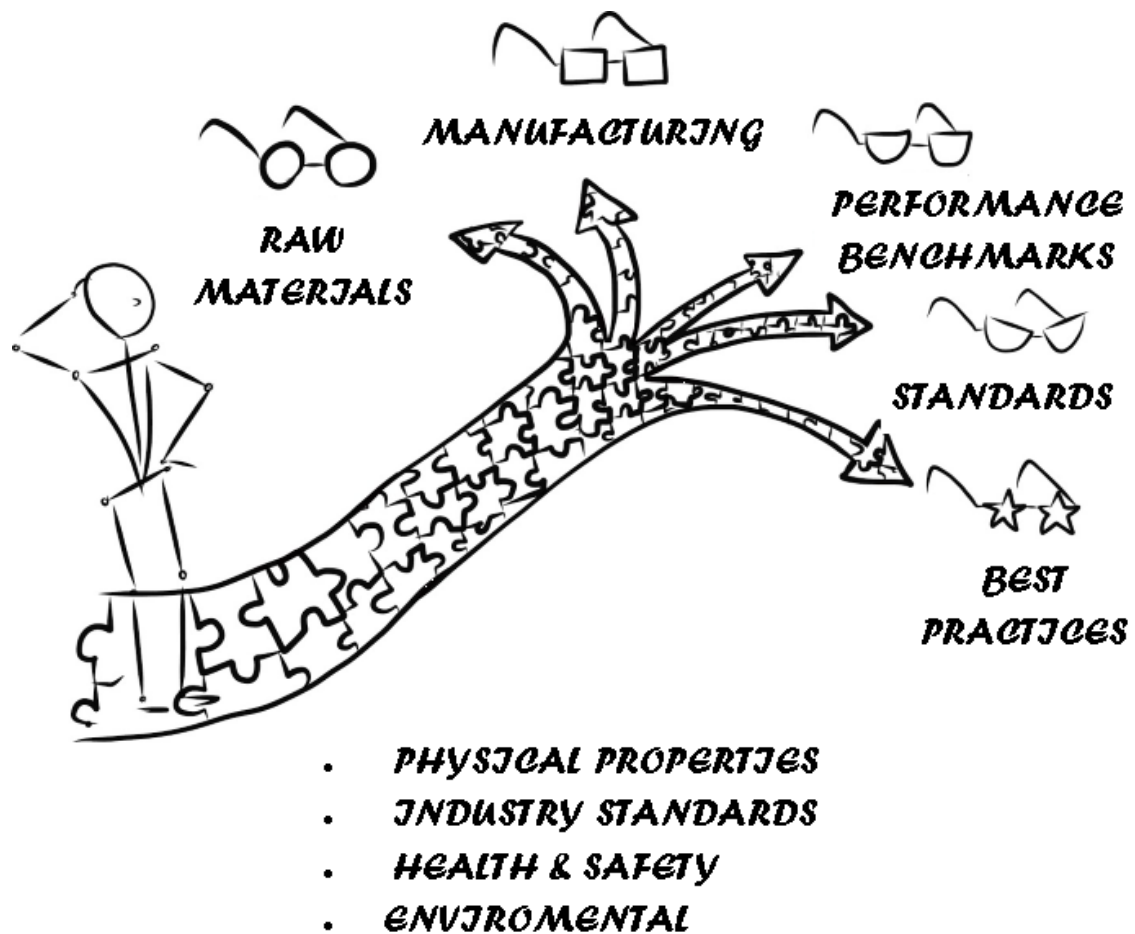


Figure 4-17 Design Journey is a Need Finding Puzzle Interacting with Many Stakeholders

Need-finding research of the form and function drivers is an essential element of identifying competitive benchmarks. However, only focusing in this area limits the opportunity for design-based differentiation. While form and function can serve as a distinctive differentiator, purposely seeking additional opportunities beyond form and function greatly expands the value creating potential of the design process. These additional form and function needs appear throughout the total product experience.

As Levitt has articulated, users seek the problem or need-solving experience, not the functional way the problem it occurs. Thus, reframing these needs from a perspective of questioning the job that the stakeholder is seeking to satisfy allows for radical new solutions and designs for the designer. For example, Uber and Lyft have reframed the taxi experience disrupting that traditional marketplace.

4.5.6 Need Finding Beyond Form and Function in the Unexplored White Spaces

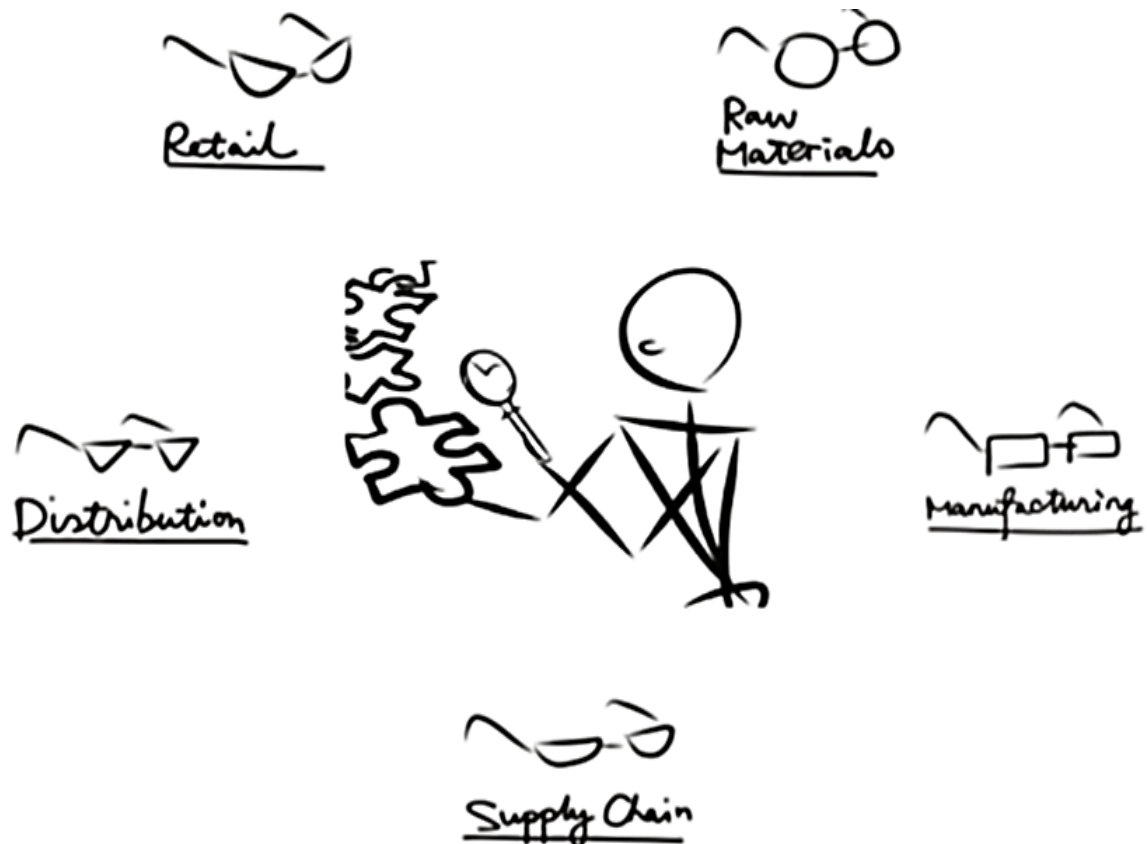


Figure 4-18 Strategically Focus on Value Creation throughout the Consumption Chain

Research of the needs of all stakeholders both internal and external, beyond form and function, is a powerful strategy to create a new experience. Oftentimes these needs are not directly tied to the product, but can be addressed in a new design without sacrificing cost or performance. The designer can identify opportunities to meet the needs of multiple stakeholders that are complimentary to the overall objective of raising competitive advantage.

Designing new product differentiators starts with research and benchmarking of the existing knowledge solution. This research establishes the existing knowledge reference benchmarks necessary for designers to benchmark the expectations and mentally model the potential new knowledge creators. By identifying multiple value creation opportunities, the designer can access the situation in the competitive context to determine which opportunities can have the potential to create new value.

4.5.7 Patent Research Provides Insights into Functional and Protected Technology

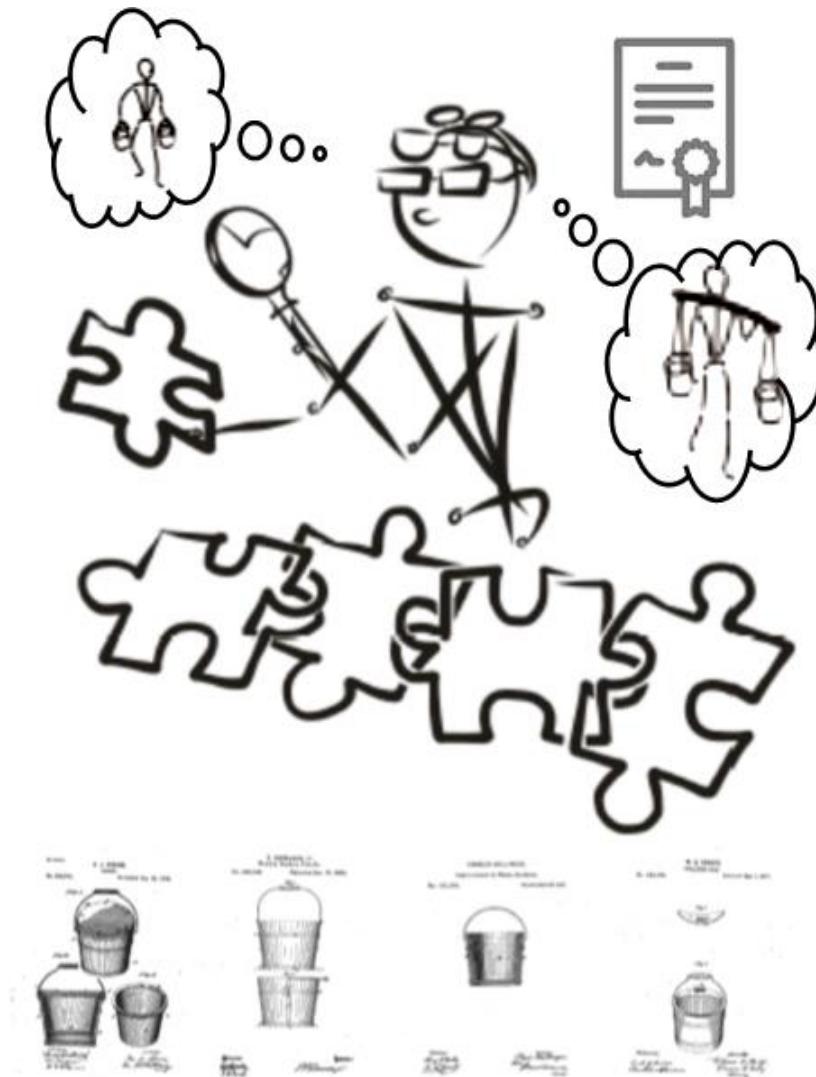


Figure 4-19 The Design Journey Must Also Benchmark the Existing Knowledge Solutions

Researching the function and form space including patents provides the existing technical knowledge of the product discipline. Patent research allows the designer to understand which patents are active and which have expired, providing insights into the existing technology benchmarks. Researching patents can also act as historical technical roadmaps for reference in new product design. Benchmarking the existing technology space with patents provides insights into potential protectable new knowledge spaces. This process can prevent unintentional misuse of protected technology and provide a reference for strategically designing one's own protectable functional design attributes into novel spaces.

4.5.8 Research the Unexplored White Spaces for Seeking Competitive Advantages



Figure 4-20 Designers Seek the Unexplored White Spaces for New Opportunities

This high bar of competition has created a situation of high stakeholder expectations in competitive marketplaces, and problem solving is insufficient as a standalone strategy to bring competitive advantage. New product designers seeking to create competitive advantage in commercial marketplaces must strategically research and identify needs that can create value in multiple white spaces that allow for the creation of novel and protectable differentiators through their design quest.

Designers who think beyond the performance-based problem solving aspect of design when creating new products will put themselves in a strategically advantaged position. While problem solving is necessary, and itself can be a significant differentiator, if the product experience does not hinge on it the stakeholders will look further to judge new value and competitive advantage. Designers have a choice: chase the competitors expectation bar or set the bar themselves, forcing the competition to react.

4.6 Analysis Heuristics

4.6.1 Stakeholders Can Only Explain What They Believe to be True



Figure 4-21 Designer as Researcher Diagnosing the Stakeholders' Needs

The designer has a unique analysis challenge when interpreting information; he must approach the stakeholder statements as an analyst seeking to understand what the true needs are. Oftentimes stakeholders cannot express their needs in a future embodiment, they only know the existing reality. Through various design methods, designers can gain insights into those unexpressed, under-expressed, and unarticulated needs that can provide opportunities for differentiation from the existing knowledge solutions.

There is a trap in this process, as the stakeholders will often verbalise what they know, and they cannot express what they do not know, creating ambiguity for the designer in understanding what the need truly is for the stakeholders. These insights provide directions for mock-up and prototype testing, necessary to confirm the stakeholders' preferences to the designers' new propositional models.

4.6.2 Frame & Re-Frame the Stakeholder Needs Beyond What You Hear and See

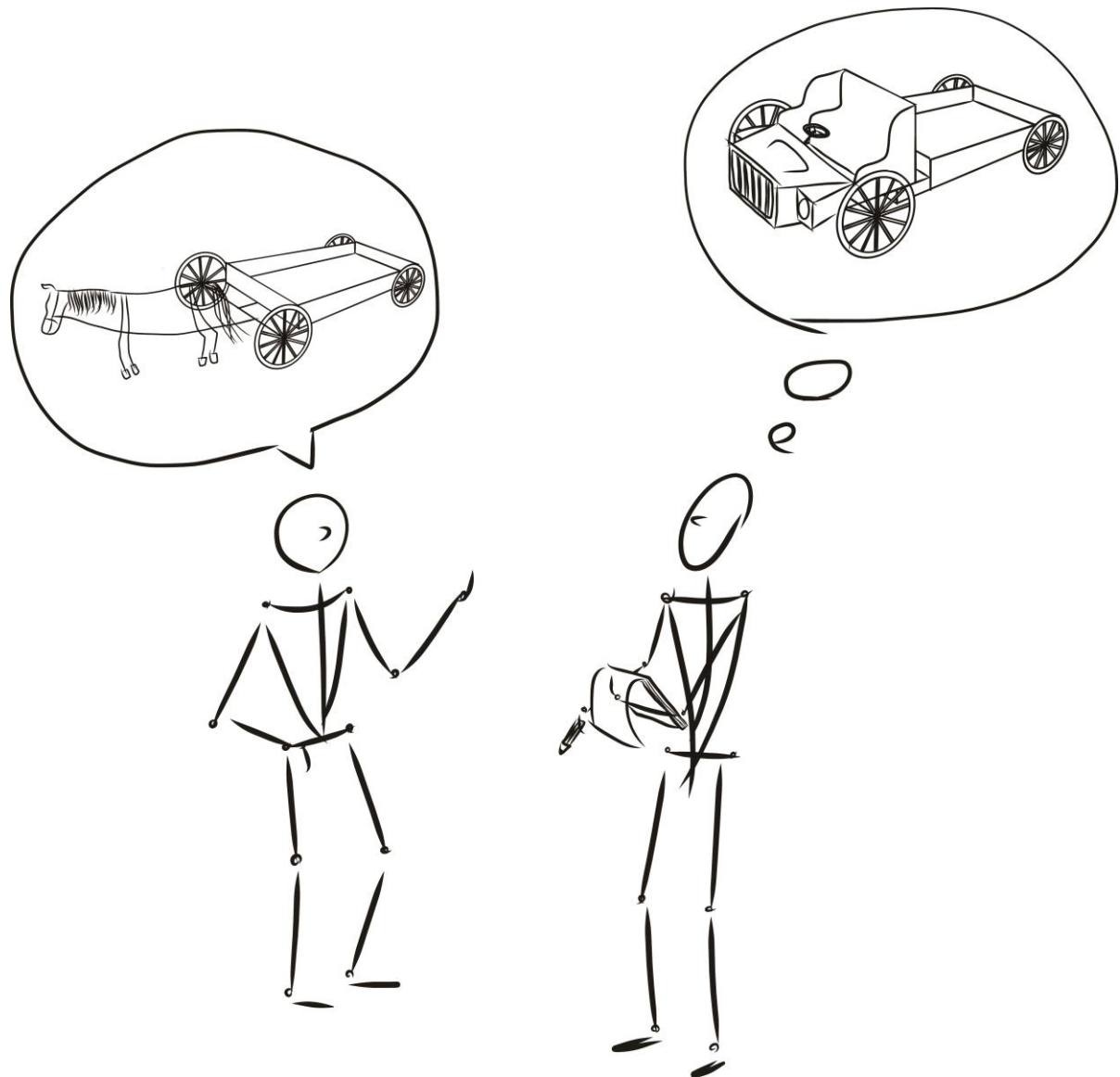


Figure 4-22 Empathically Frame and Re-Frame Needs beyond Existing Conceptualizations

The process of framing and reframing the problem and needs provides multiple perspectives to work with. Designers must be able to empathically frame the needs beyond stated performance aspects of the experience that they hear from internal and external stakeholders. Needs arise from the behavioural, cognitive, and endowed relationships and biases that stakeholders have pre-established for the problem-solution experience. In addition, stakeholders cannot tell you what they do not know. Thus, listening to the needs requires reframing these needs beyond the existing solution that the stakeholder has become accustomed to. (Christensen and Cook 2005) This empathic need finding requires the designer to see the same problem and needs from many internal and external vantage points and possibilities.

4.6.3 Analysing Which Differentiators Add Value Across the Consumption Chain

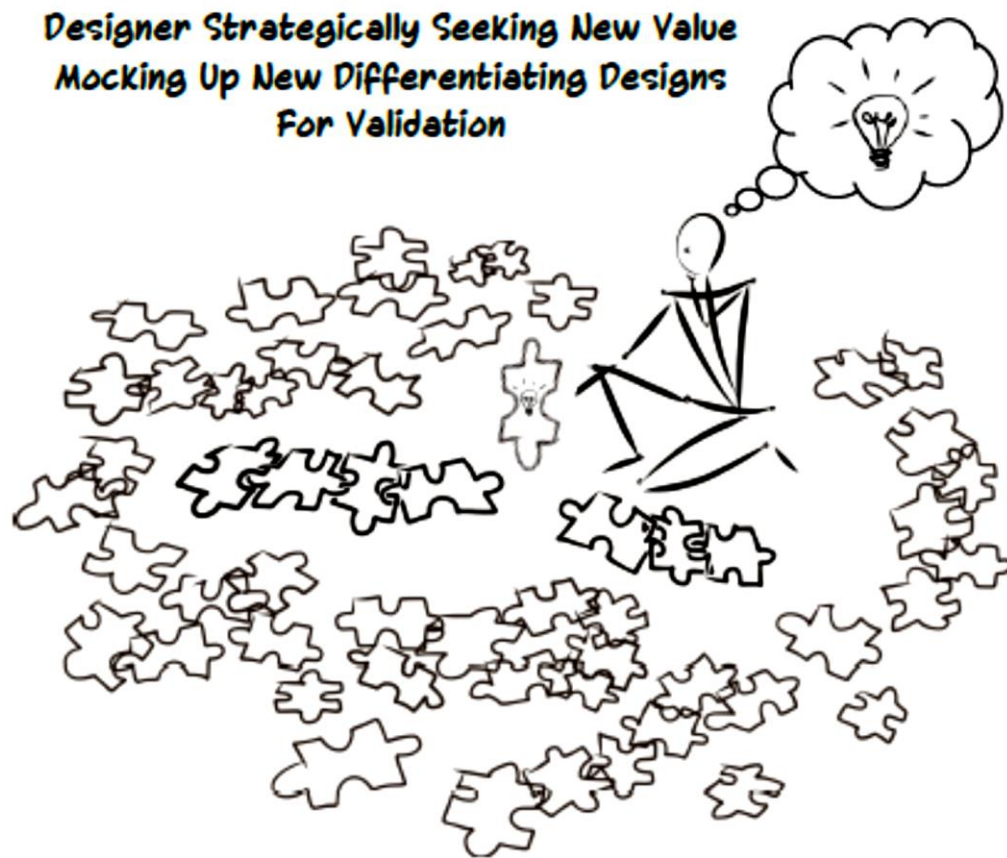


Figure 4-23 Needs That Can Add Value Must be Identified in Order to Bring Focus to the Project

Analysing those currently unmet stakeholder needs and uncovering competitive benchmarks for commercial viability is a puzzling process. The designer must understand the competitive dynamic, comparing and contrasting the identified needs with both the existing and propositional solutions. The designer must pursue only those differentiations that meet or exceed these performance expectations, focusing only on those needs with the potential to create new value and competitive advantage for differentiation of the new product experience.

This is a dialectic synthesis of the research of the earlier stages of the process. While the research, analysis, and synthesis stages are arguably separate, they actually are iterative with continual validation of the assumptions of the design process research. This puzzle evolves dynamically, with the existing competitive dynamic of the marketplace as the benchmark, and the propositional design strategy identifies the white space focus for new differentiated design opportunities.

4.6.4 Strategically Analyse Multiple Value Creators for Your Solution

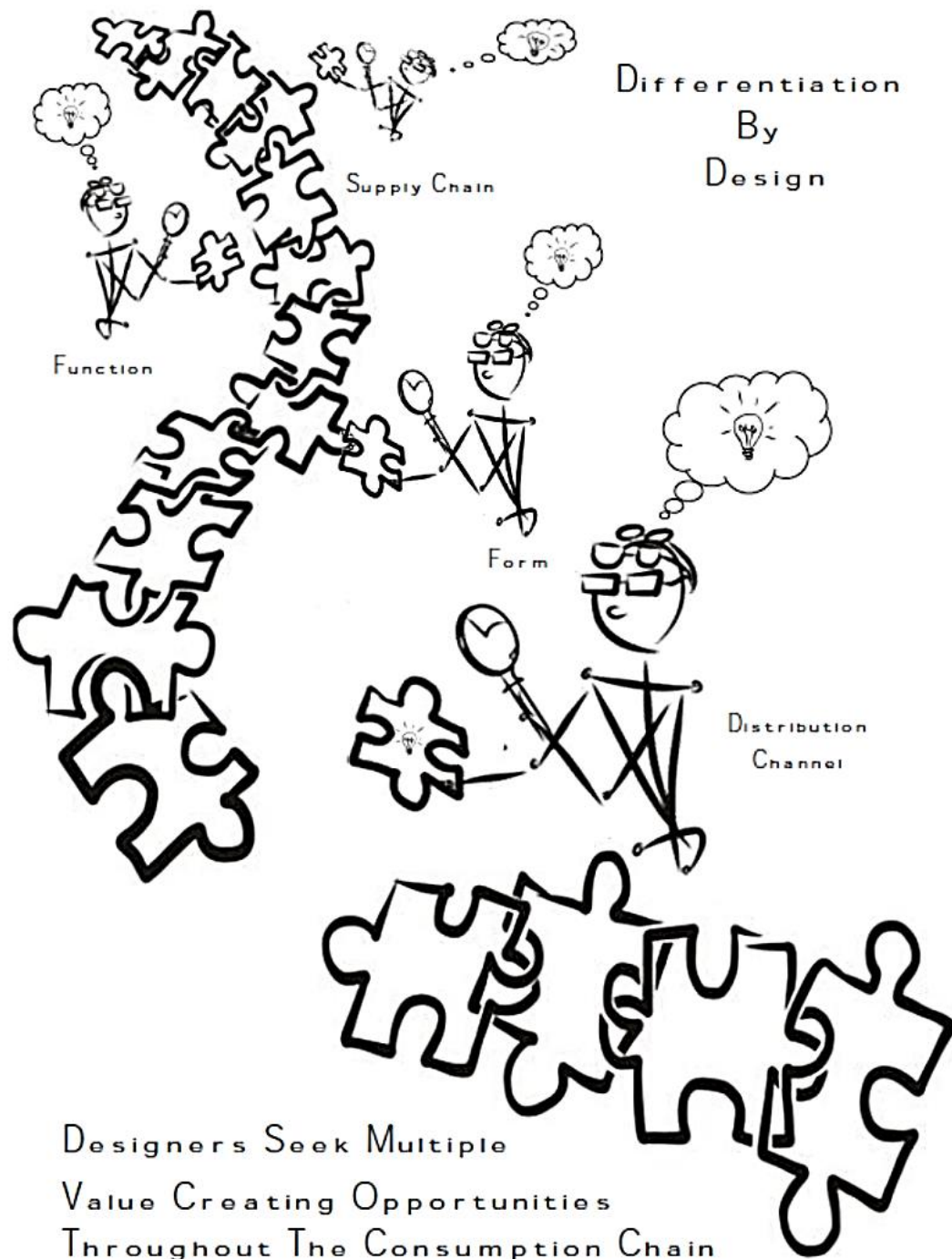


Figure 4-24 Designers Seeking Opportunities Throughout the Consumption Chain

New knowledge strategic synthesis in white spaces requires designing new knowledge solutions where there are no satisfactory existing knowledge solutions. Analysing for white space propositions strategically brings focus to multiple opportunities for creating novel solutions protectable by intellectual property strategies. Beyond the creation of differentiation, securing commercial protection is necessary for the viability of the new product design in the marketplace.

4.6.5 Integrate Intellectual Property Analysis into Your Design Novelty Seeking

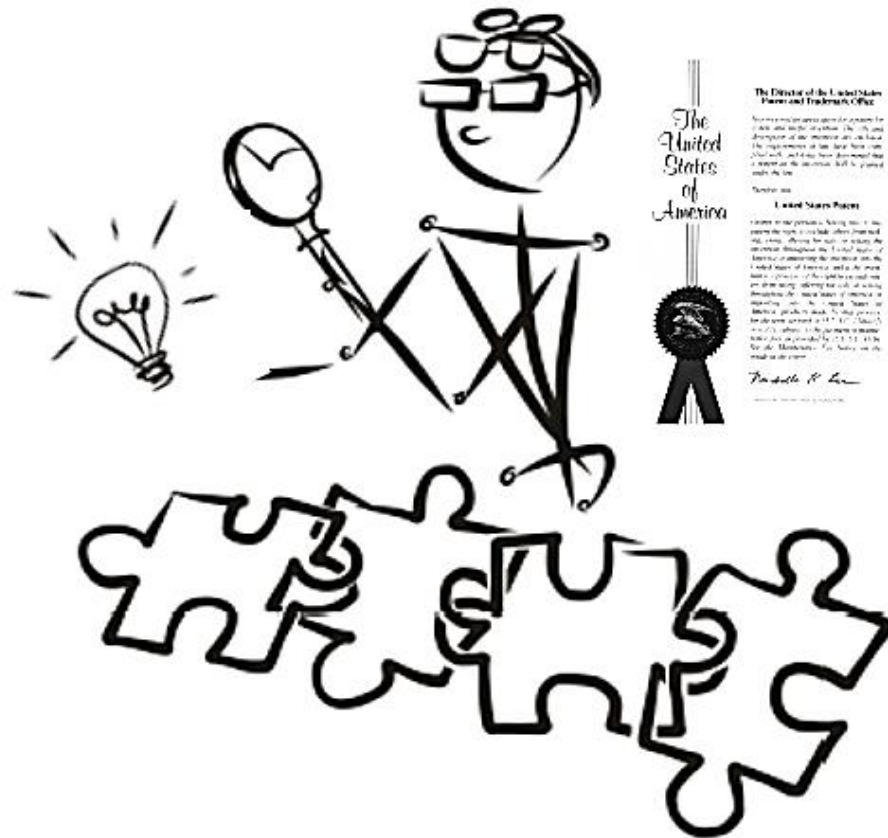


Figure 4-25 Commercial Sustainability Requires a Designerly Intellectual Property Integration

Designing a new, value-creating product is a challenge, as many pre-existing product solutions have established prior art in the marketplace. Thus, achieving a value-creating and competitively advantaged new product solution is challenging among all the pre-existing knowledge in the marketplace. Analysing the existing knowledge space is necessary for designers to strategically seek a new knowledge technical pathway.

Patent research and building off the patent research process of benchmarking the existing technical space allow for novelty seeking through the design process. This novelty must be sufficient to create a strong patent for the solution as a new invention so that the product line can be protected from copying in the marketplace.

4.6.6 Novel Identity Analysis, Experience, and Awareness for Branding

The Differentiations Must Fit Together In A Plan That Builds A Comprehensive Identity For The Experience

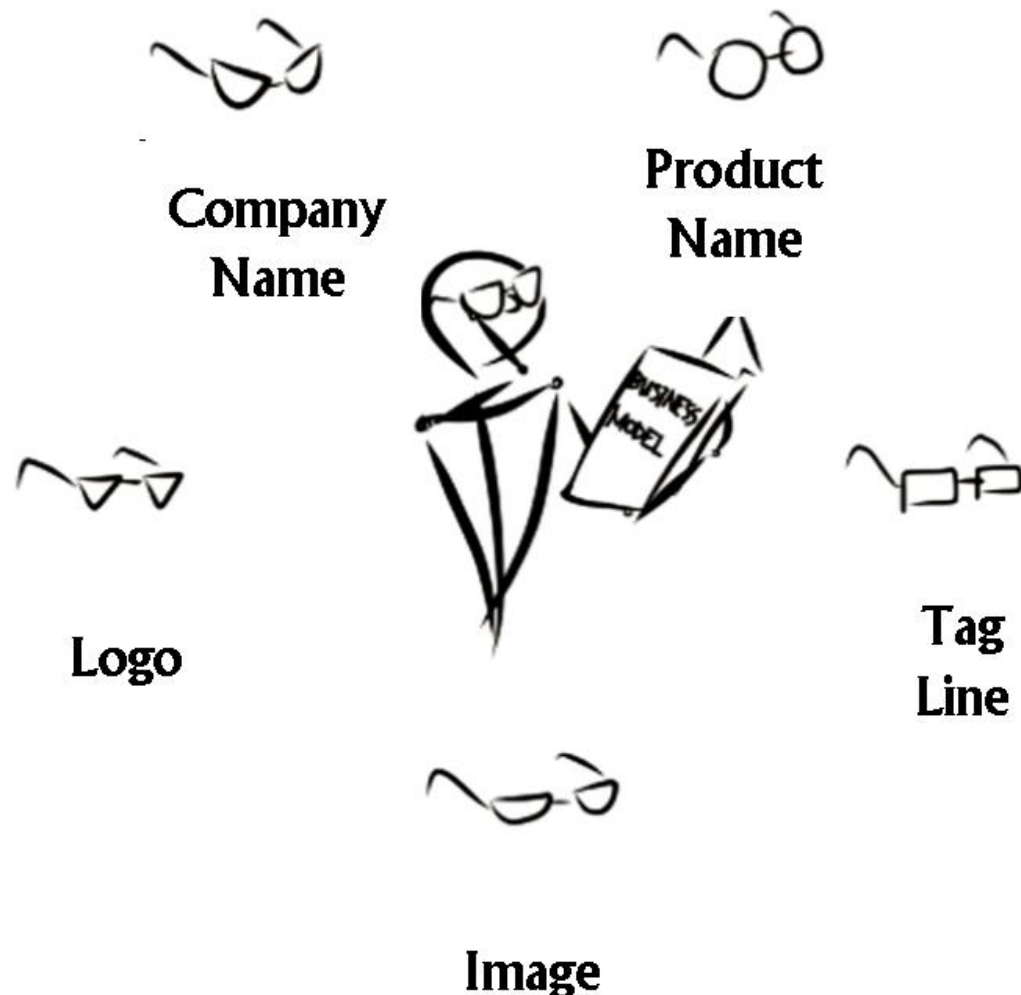


Figure 4-26 Brand Identity is Designed Early in the Process Reflecting the Designed Advantages

New products rely on marketplace awareness for stakeholder consideration. Whilst brands are the result of successful products, whose identity acquires meaning and recognition by the marketplace, new products often start as unknown products. To establish a brand identity means to acquire a secondary meaning with the product name, image, or other associated communication. Designers must position a new product identity within the design process, so that the identity can become a brand identity if the stakeholders recognise that secondary meaning. Entering the marketplace without an integrated design identity undermines the ability to effectively create one if the product demonstrates market viability and scales without an identity.

4.7 Validation Heuristics

4.7.1 Stakeholder Choice Validation is the Experimental Laboratory for Designers



Figure 4-27 Validating with Stakeholder is the Laboratory of the Designer's Research

New products are not tested beyond functional performance for value creation accurately in a laboratory; the experimental laboratory for new product development is the competitive marketplace. Often the designer creates a testing strategy that accurately measures the competitive response as part of the design process; validation should compare the existing solution to the new propositional solution in the context of the marketplace. This process evolves throughout the design process, from sketches, mock-ups, and prototypes, to pre-production testing in the marketplace.

4.7.2 Employ Methods to Objectively Determine if You Meet the Design Requirements



Figure 4-28 Stakeholder Validation is the Metric of Competitory Design Practice

Validation with both the internal and external stakeholders is an iterative process that proceeds through the early stages of the design process in a continuous loop of testing the new design propositions. This validation and testing is necessary to understand the value judgements of the stakeholders, where your design work is meeting your objectives, and where you are falling short. It is often said that when exploring new knowledge, we are failing our way to success.

4.7.3 Validate the Performance Metrics Through Rigorous Testing to Standards

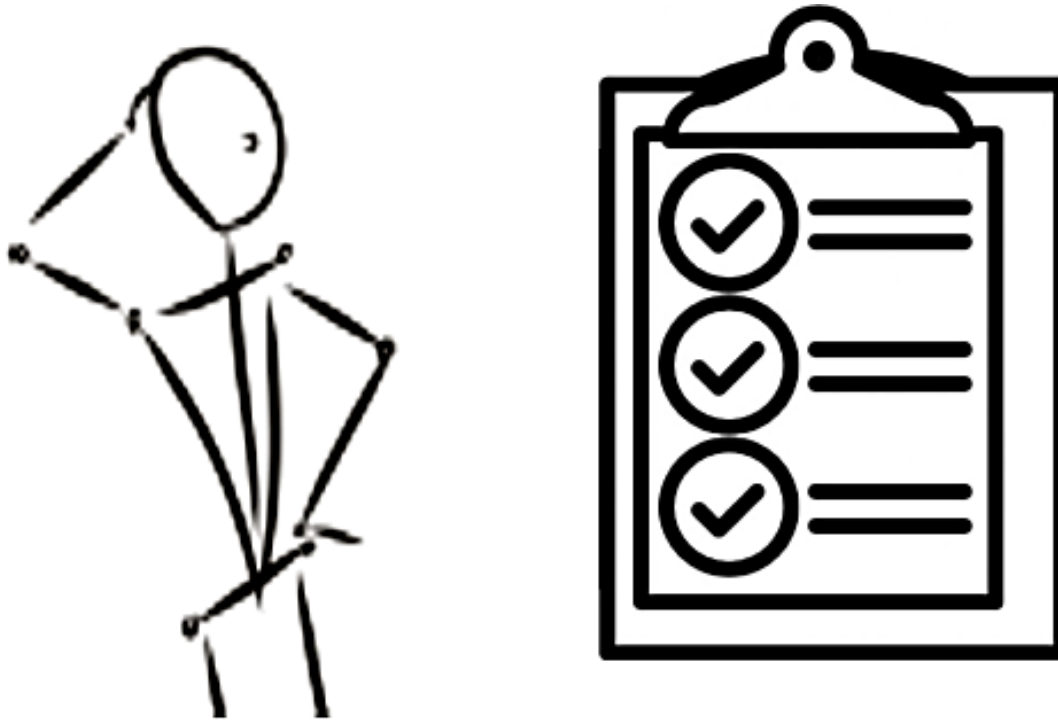


Figure 4-29 New Design Requires Best Practice Performance Validation

Care must be taken when creating new design knowledge; creating new product change is a serious responsibility and must be treated as such. Reusing existing knowledge at times may seem like a low risk, but one cannot assume that using existing knowledge but changing the context will share the same level of risk. Much of the design process is a qualitative iteration of new ideas having not been tested in context or vetted for viability.

Validation with all stakeholder groups is necessary; thus, the process must rely on the testing protocols of the established best practices of the discipline. Blindly accepting models or simulations of performance without pursuing the best available testing is unethical and unprofessional practice. Unintended consequences can arise and the designer must continually guard against assuming that the new product is performing without doing the appropriate performance testing.

4.7.4 Validate the Safety and Compliance with Industry Standards and Regulations



Figure 4-30 New Design Requires Best Practice Standards and Safety Compliance Validation

Designing to meet or exceed industry and governmental standards and regulations is necessary for commercial product design. This process starts with researching and benchmarking the existing expectations, as well as understanding how the existing standards would apply to new knowledge solutions. At times, new knowledge solutions disagree with standards and regulations derived from existing knowledge solutions. A conundrum occurs when seeking new knowledge solutions and having to meet existing knowledge standards: existing standards tend to force new solutions into existing product paradigms.

4.7.5 Validate the Business Model Strategy-Viability and Commercial Sustainability

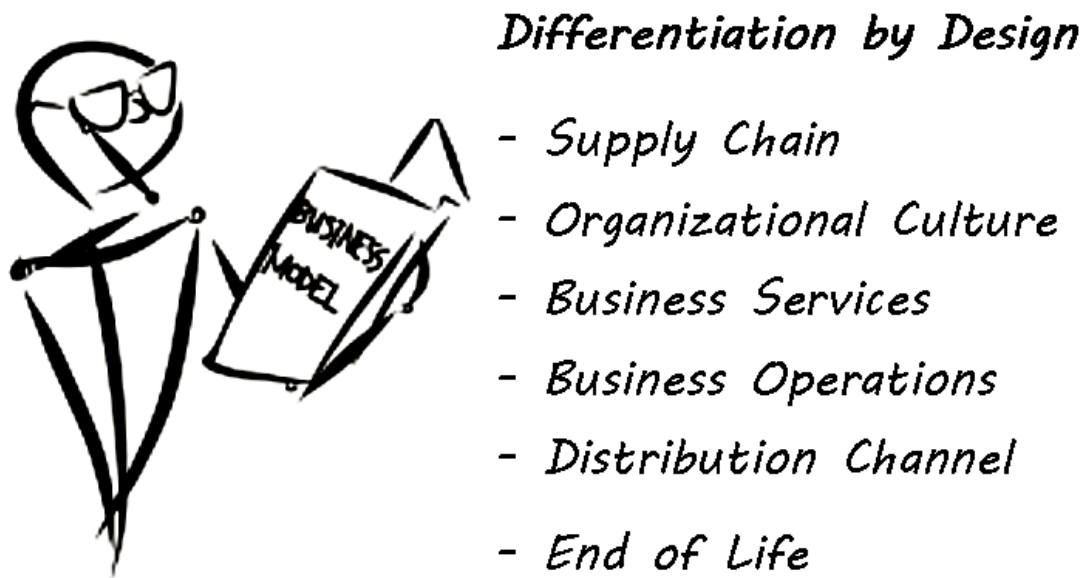


Figure 4-31 New Design Requires Best Practice Business Model Validation

Typically, commercial product success involves integrating the new product into an existing business model. Designers should recognise that product change also presents opportunity to design a new business model that supports the pioneering of a new, integrated experience. In contrast, new product introduction by existing businesses is often constrained by the legacy relationships of the existing business, supply chain, operational systems, distribution channel, and endowed product identity-branding.

In this case the business model can act as a constraint. In circumstances where the new product design is also pioneering an entrepreneurial business model, the complete consumption chain is open to design value creation, and the differentiation by design strategy provides many opportunities to seek advantage over the legacy benchmarks of the competition. Designers should always explore the new product design opportunities in the entrepreneurial way, even with existing businesses, as a best practice of researching the new knowledge space for the best future advantage.

4.8 Concluding Reflection on the Data

Upon reflection, as my design practice evolved, my philosophical design perspective expanded beyond the traditional design engineering focus seen in cases one and two. Promotion into management challenged me to focus my efforts not only on form and function, but also on overall financial performance. My role as Business Manager both challenged and changed my perspective of how design interfaces with business beyond the technical challenges of product development. Product design became my overall strategy for creating competitive advantage in business.

Managing multiple organizations' competitive positions in the marketplace over the years enlightened me to the power of design-based strategic competitive differentiation strategies for the competitor-focused practitioner-designer. These opportunities for differentiation expanded for me as my managerial role allowed me operational influence across functional specialties, including both internal and external stakeholders of the organizations I worked with. As seen in case three, the Bionic Wrench, this process is a purposeful strategic designerly process and, from my perspective, is the design process of strategic designerly enquiry. This qualitative and quantitative research is the foundation of an academic discipline of product design based on the creation of new value and competitive advantage.

Often, in practice, the problems practitioners encounter arrive as requirements, as stated without discussion or investigation. These problems are self-evident when your stakeholder provides the needs, often stated as the final specifications of their expectations, leaving little doubt as to what the practitioner is expected to accomplish. When a client approaches a bridge builder and provides the requirements for a bridge he wants built, the bridge building practitioner uses the stated requirements given by the customer, analyses the problem based on these requirements, and applies the existing knowledge of bridge building to create the bridge. This is professional practice, using the rules-based, existing best practice, professional knowledge to design a bridge. However, what happens when the existing knowledge of practice is insufficient to handle the challenge? This is a different opportunity in practice, where the existing knowledge cannot meet the need; the practitioner must approach the opportunity differently and use a designerly form of thinking to create new knowledge to solve the problem.

When existing knowledge falls short for addressing the problem, the practitioner must now determine how to solve the problem in a new way, or else abandon the problem-solving effort. A knowledge gap exists where the existing knowledge of professional practice falls short. If the practitioner has sufficient experience, proficiency, and motivation, it is a proposition of this research that he or she becomes a designer in practice, accepting the designerly quest of seeking a new knowledge solution for the situation. This new knowledge challenge, like most endeavours, offers a spectrum of outcomes, from simple new knowledge evolution in order to solve the problem, to a more challenging new solution that competes at a higher level, to a creation of new knowledge that disrupts the paradigm.

I have lived in this creative spectrum for years, often designing simple solutions in practice, as well as encountering situations requiring invention and differentiation beyond form and function in order to compete. New product design is more often on the more challenging side of the spectrum as the competitive commercial playing field makes it so. I have found that these new product design problems, especially the entrepreneurial ones, are much more challenging. While starting with diagnosing the problems and needs, the process continues deeply into the opportunity interactions for creating advantaged and differentiated solutions. Whereas the practitioner can often start with explicit functional requirements, those requirements are the start of a design process that extends across and deep into the whole consumption chain of stakeholders.

In addition, seeking new opportunities to reframe the situation beyond form and function requires the designer to need-find potential new value creators for the product experience in the process. This need-finding research process is qualitative in nature and relies on skill sets beyond the structured scientific worldviews and methods of my education and training; seeking opportunity to create new value required me to develop these skills. After successfully discovering unmet needs and addressing them through my creative efforts, the testing process circles back to the quantitative methods of validation in harmony with the qualitative methods of design.

This reframing of the problem around a design-based, new knowledge creation paradigm versus a practice project paradigm challenges the designer to expand the search for more enhanced need identification and insights into new value creation. In practice, I discovered that exploring and discovering unmet, under-met, or unarticulated needs was critical, and that these needs existed throughout the

consumption chain and amongst all stakeholders interacting with the design challenge. This need-identification research draws upon non-traditional qualitative skills for the technically trained practitioner in the observation of behaviours, researching of choice drivers, validation of needs, and optimization.

In seeking competitive commercial advantage, I found myself employing enhanced methods of competitory strategic thinking and research in my work. Beyond traditional problem solving of apparent problems, commercial product design demands the designer seek to understand those unmet needs that lead to novel, useful value creation and competitive advantage. These needs can be analysed to identify those needs that could add value for the stakeholders, allowing me as the designer to bring intense focus to those value-creating opportunities and not spend time and effort working on needs that could not evolve into competitive advantage.

Research on the problem became a peremptory part of the process. It rose above the simple form and function research of technical practice and industrial design, into multi-level need insights that were dependent on my initial design research, creating strategic focus for the project beyond the technical needs. The heuristics described in this chapter are at the heart of competitory new product design and development. This practice rises above the traditional engineering design process for new product development, where the engineer must become a designer when seeking those opportunities to create new value and advantage in a sustainable way that arise out of practice.

In this chapter, I have explored how designers employ these designerly heuristics to address these wicked and ill-defined challenges in practice. These designerly heuristics are not rule-based algorithmic steps to follow; instead they are heuristic rules of thumb. The designerly heuristics do follow an iterative pattern of research, analysis, synthesis, and validation, but they do so in an exploratory and designerly way, leveraging the designerly quest characteristic of our human nature. In the following chapter I will present a model of how this research works in practice through a framework developed for this thesis to explain the dynamic interactions of how and when a practitioner pursues new knowledge when confronted with the knowledge gap in practice.

5. Synthesis from this Research of Practice - Introduction

Practitioners of design, a category including essentially everyone, touch design in various places. Many are not aware of touching anything and are oblivious to the designing they do. Others, professional designers of one form or another, are very conscious of the designing they do, but like the blind men, they tend to define the total elephant in terms of the part they are touching.

Raymond Willem, “Varieties of Design”

In this chapter, I will synthesise the emergent themes from the research of how designers strategically create new value and competitive advantage in new product marketplaces. I introduce a new knowledge contribution framework for the practice-design-compete relationship in new product design and development. This strategic design process is based on the Competitory Action Model (CAM) Framework. Embodying the designerly heuristics presented in Chapter 4 are the contributions to new knowledge of this thesis. The thesis explains how (the heuristics) and when (the CAM Framework) design creates value and competitive advantage in new product marketplaces.

5.1 Purpose of This Research

Research is what I'm doing when I don't know what I'm doing.

Wernher von Braun

My thesis aims to study the design practice of small- and medium-sized enterprises (SME) in the development of a theoretical contribution for explaining the process for creating design-based commercial competitive advantage. The purpose was to create a contribution to new knowledge and academically rigorous new theory that could explain to practitioners, designers, and academics how the design process creates competitive advantage. In addition, the research describes an enhanced, new product design process pedagogy arising from a strategic execution of differentiation by design strategy as a designerly method to focus new value creation and competitive advantages in new product design. This strategic differentiation process brings focus to the designerly forms of enquiry, built on evidence-based research and driven by the designer's quest for targeting the best opportunities to create value in the practice of new product development. New theory has also arisen, and a CAM framework has been created in support of how practitioners act as designers in seeking new knowledge pathways for creating competitive advantage-based innovation in any disciplinary practice.

5.2 Summary of Research Protocol Used in this Study

Have a bias toward action—let's see something happen now. You can break that big plan into small steps and take the first step right away.

Indira Gandhi

Primarily a reflective practice, this research has relied on a mixed method study in the analysis of data provided in three new product design histories, literature review, interviews, and a reflection on action in practice and teaching. As Gandhi's quote suggests, the action-taking bias of this research focused on the small steps for researching the past design practice, while a larger picture arose from this research. The Competitory Action Model (CAM) framework only evolved much later when I was well into the study, seeking to explain the nature of the practice-design dynamic in new product development. These contributions arose from a Grounded Theory methodological process detailed in chapter 3, employing an open-ended approach utilising coding, analysis, and synthesis of the data in the evolution of the new theory contribution.

Perry's Five Chapter thesis model:

Chapter 1 introduces the research and the research design with focus on developing an academically rigorous and robust research design plan.

Chapter 2 introduces the Literature Review of Design and Innovation, with a thorough analysis of the thematic contributors of this research.

Chapter 3 describes the Methods and Methodology strategy employed in the practice of the thesis research.

Chapter 4 reviews the themes that emerged from the analysis of the three cases that provide the data for the research, ending with 10 designerly heuristics supporting a Differentiation by Design theory for an enhanced pedagogical approach for teaching designerly enquiry as a strategic activity, not a science of design roadmap.

Chapter 5 provides a thesis summary, contributions to new knowledge, design heuristic framework, limitations, and next steps for the research.

Finally, beyond the research itself, potentially the designed protocol of this thesis offers an example of how research could arise out of practice for researching the design process of an experienced design practitioner, reflecting on practice, as an academic design researcher, further detailed at the end of this chapter.

5.3 Addressing the Five Research Questions of this Thesis

A problem well stated is a problem half solved.

Popularly attributed to Charles Kettering

1. How and when do practitioners determine it is necessary to seek new knowledge (design), rather than use their existing domain knowledge in practice?
2. How and when do practitioner-designers determine the value benchmarks or stakeholder choice drivers that act as the metrics for judging competitive advantage in commercial markets?
3. How and when do practitioner-designers strategically identify and design differentiators that add value and compete for the stakeholder's choice in new product design?
4. How and when do practitioner-designers sustain the organization's competitive advantage in the marketplace?
5. Is there a potential new differentiation by design theory for explaining the how of creating competitive advantage in new product design and development?

ADDRESSING QUESTION 1 - How and when do practitioners determine it is necessary to seek new knowledge (design), rather than use their existing domain knowledge in practice?

5.3.1 New Knowledge-Based Problem Solving Drives Design Practice

Having a well-defined problem allows the designer to bring focus to the challenge; working on stated problem requirements is very much a disciplinary practice. Often in the context of practice, the term design is used interchangeably with the practice of solving problems with stated requirements addressed by existing disciplinary knowledge. For example, an engineer employs his skills in practice. There is also the design situation where the practitioner lacks stated requirements, and the design challenge becomes much more demanding in the definition and focus. In new product design, the competitive dynamic further complicates the design challenge, as the intended new product design must create commercially viable business advantage. While design is characterised as problem solving of stated problems, this is rarely the situation in new product design, where the challenge is strategically more complex.

Many design challenges start with known problems as cases one and two in this study reflect, and often in practice, a designer will seek to solve the problem with existing knowledge of practice. In circumstances where the existing knowledge of practice falls short, a knowledge gap appears for the practitioner. When a knowledge gap in practice occurs, it is both a challenge and an opportunity for practitioners. This gap defines and provides opportunity for practitioners who have the desire and proficiency to pursue a designerly quest to create a new way to solve the problem.

The first two cases of the study had obvious knowledge gaps in their embodiments, and the design problem-finding was focused from the beginning of the projects. While finding the solution was a vexing technical challenge, it was much more focused than the open ended search for a real problem as seen in case three. For the third case of the Bionic Wrench, a number of knowledge gaps created a very challenging problem-finding and focusing process. Designing into those new opportunity white spaces, especially when required to create competitive advantage, the front-end design research challenge becomes a critical component. There is a spectrum of design, from skill-based problem solving seen in practice, to complex research projects with competency outcome pressures, as in new product design.

ADDRESSING QUESTION 2 - How and when do practitioner-designers determine the value benchmarks or stakeholder choice drivers that act as the metrics for judging competitive advantage in commercial markets?

5.3.2 New Value Benchmarks Require Strategic Re-Framing

As Levitt has articulated, “*People don’t want quarter-inch drills. They want quarter-inch holes*”. Opportunities often arise when reframing the customer needs beyond the existing paradigm or solution. Reflecting on the above quote, a practitioner seeking to create ¼” holes may seek to optimise the traditional drilling functionally by strengthening the steel of the bits, improving the drill motor, implementing better cutting fluids, or employing any number of existing practice or knowledge methods of the discipline. Whilst this approach can work in many situations of practice, when seeking to create competitive advantage, it lacks the strategic differentiation focus for creating advantages needed beyond functional experiences to compete as a new product solution. As discussed previously, thoroughly mapping the consumption chain and identifying the stakeholders who act as the judges of a new product’s success, and their ¼” hole needs, beyond function can bring focus not only to the problem-

solving but to a differentiated value creating solution experience involving form and function and competitive strategy.

For example, when thinking about a better way to create $\frac{1}{4}$ " holes, and seeking to create a more competitive and differentiated solution, the practitioner must reframe the challenge and put the designer's hat on to focus on creating new knowledge solutions beyond the existing knowledge solutions. Reframing the $\frac{1}{4}$ " hole, the designer can foresee other ways of creating holes: stamping the holes into thinner materials and lamination, using a laser or a waterjet to create the holes, possibly using an acid to soften the material to permit easier drilling, or maybe using a woodpecker. This sounds nonsensical to think of, but a woodpecker inspired a drilling invention in 1947 by inventor R.E. Barr, who patented a "Woodpecker Drill" to drill through tough materials by mimicking the bird ([Barr 1947](#)). The image below (see Figure 5-1) demonstrates how a reframed idea like a woodpecker-inspired drill can evolve over time, creating new value and advantage for the drilling of hard materials like rock and concrete.

This item has been removed due to 3rd Party Copyright.
The unabridged version of the thesis can be found in the
Lanchester Library, Coventry University

Figure 5-1: Design of the Woodpecker Drill (Singh 2014)

ADDRESSING QUESTION 3 - How and when do practitioner-designers strategically identify and design differentiators that add value and compete for the stakeholder's choice in new product design?

5.3.3 Strategically Designing for Differentiating Competitory Advantage

Once the design problem-finding challenge comes into focus, often the resulting function or form solutions alone are often insufficient to create enough competitive advantage for sustaining a commercial product pioneering effort. Seeking to create competitive advantage, the designer must venture into the needs of the product experience beyond the functional problem and its immediate stakeholders. New value-creating opportunities are awaiting discovery throughout the consumption chains of internal and external stakeholders. This is often the case when pioneering new knowledge solutions into new markets entrepreneurially as seen in case three.

Seeking differentiated advantage beyond form and function is a basic heuristic for all new product design.

Opportunities for differentiation appear through researching the interaction spaces beyond form and function, seeking unmet needs as additional new knowledge gaps to explore. New products in existing viable markets, as seen in cases one and two, have established supply chains, distribution channels, and business models. While these areas can evolve with any new design project, existing business often do not have the additional burden of pioneering the whole business structure. Entrepreneurial new product design often requires the pioneering of the product, supply chain, distribution channel, and business model, as well as a scalable new product experience. At the extreme level, the designer is not just designing a new product, but designing a new business to support the new product's commercial realization. This is a common dynamic in SMEs, especially entrepreneurial ones.

This entrepreneurial challenge beyond designing a new competitive product and a complete new business eco-system can often be viewed as a disadvantage. However, when framed as a potential for creating multiple new value opportunities, it can strategically become an advantage. As seen in the Bionic Wrench case, pioneering the whole business from concept through commercialization is daunting. Yet, when executed proficiently, these challenges provide differentiating opportunities beyond the functional problem solving to strategically create value. The designer has the ability to recreate the supply chain, distribution channel, and business model as seen in case three. Although challenging, this ability to raise the competitive bar in areas where existing businesses have established legacy relationships is itself a strategic advantage for new product developers.

ADDRESSING QUESTION 4 - How and when do practitioner-designers sustain the organization's competitive advantage in the marketplace?

5.3.4 Not all Design Opportunities Create and Sustain Value Equally

The range of outcomes of the design process can fall within a spectrum of competitiveness, from no new value creation, where a design may be new but not sufficiently competitive and as such not commercially viable, to disruptive value creation. Some design is new and novel and can achieve the benchmarks for patents and invention, although being patentable does not mean commercially valuable or viable. At times, the value is incremental; this may be advantageous depending on

the market circumstances. Incremental improvements in products that have established market presence may be improvements; for new market entrants, incremental improvements would not suffice for pioneering a new commercial enterprise.

For new product entrants, it is difficult to win the stakeholders' choice by simply offering an incremental solution beyond what they are currently using, thus new product entrants must seek sufficient new value with competitive advantage to motivate the stakeholders to switch their preferences. In addressing Thiel's research of product innovation, *Zero to One*, T. Woods states, "If we are truly talking about innovation, then the product will not be an incremental improvement. For it to be an innovation it must be 10 times better than what is currently available" (Woods 2015). Whilst 10 times better will always be debatable, it is safe to say that new product design must be strategically focused on creating sufficient advantage in order to be viable.

Finally, whilst there are those new products that win the users' choice in the competitive marketplace through exciting new value creation, this new value creation can be allusive, especially in mature and hypercompetitive markets where many innovations have occurred. Designers choosing new features confront many trade-offs in the design and development process. When a trade-off decision appears, the designer must ask: does this decision create for stakeholders value that they are willing to pay for? Distinguishing which design pathway has the ability to achieve new value and advantage, and which paths do not add value, is a critical design skill. These trade-offs cannot be made from an uninformed perspective; research of stakeholders and their choice drivers is a critical component of the front-end design process for new products. Designers must be in a position to make informed trade-offs that are based on this competitive strategy of value creation.

ADDRESSING QUESTION 5 - Is there a potential new differentiation by design theory for explaining the how of creating competitive advantage in new product design and development?

5.3.5 Differentiation by Design Strategy - the “How” of Competitory or Design Thinking

Whilst Design Thinking is a popular term, it continues to lack an ontology of practice (Liedtka). A question persists: how does design thinking contribute to new product design theory of practice? Business will always seek competitive advantage: how have those advantages arrived in the past, and how will they be created in the future? This research offers new theory to address this question, proposing that it is the designerly forms of enquiry described in this thesis as the ontology of design thinking in commercial new product markets. This thesis argues that design thinking is the strategic use of designerly enquiry and methods by design, what I have called in my past practice as Differentiation by Design®, a competitory focused designerly strategy for business, the strategic source of new product value and competitive advantage for competitive product markets.

This designerly quest begins when a practitioner seeks to explore the potential new knowledge white spaces when his existing knowledge of practice falls short of solving the challenge. This path is by nature is uncharted and often a pioneering effort in itself. The proficient practitioner-designer can rely on his heuristic knowledge of the design process as outlined in Chapter 4 for guidance through the process. Realistically, there are no guarantees of commercial success, although designers can raise their certainty that they are pursuing potential sustainable solutions with market viability. Through proficient design research, many of the sources of failure are designed out in the process, and the level of certainty of success can be raised. Bringing focus to these heuristic methods of enquiry is a key contribution toward an efficient and productive best practice in new product design. The potential for new value creation expands greatly when the designer becomes a multi-disciplinary strategist driven by a competitory creative vision and purpose.

5.4 Recognizing the Strategic Drivers of the New Product Design Process

5.4.1 Stakeholder Choice – the Benchmark of Commercial Viability

A sufficient level of preference by stakeholders for new product design over alternative products is a sign of potential commercial viability. Beyond the tangible drivers that can be identified in design research, these less obvious and often intangible drivers also play a significant role in measuring a new product's success. Value judgements exhibited in stakeholder behaviour are not obvious, requiring research and definition at the front end of the design process. This discernment is elusive, and determining what is advantageous to stakeholders can be a vexing research challenge in itself.

Thus, designers must seek, analyse, and understand the emotional and behavioural drivers of the key stakeholders. In reflection, I have found that these behaviours are often irrational but that they can be predictably irrational as described by researcher [Dan Ariely in his book *Predictably Irrational*](#), where he has researched these behavioural economic characteristics of humans in relation to their actions and user choice behaviours. New product value judgements and strategies must anticipate the endowed irrational characteristics of the stakeholders' behavioural economics. These emotional metrics confound businesses in the marketplace.

5.4.2 Strategically Connecting Multiple Unexplored White Space Opportunities

Design opportunities to create new value exist across the consumption chain and wherever the product touches a stakeholder from raw materials selection through supply chain, business model, distribution, and even end-of-life disposition. Strategic front-end research into these multiple opportunity spaces allows the designer to identify knowledge gaps or white space unexplored opportunities. This strategy requires a designerly paradigm-changing approach to the project rather than a practitioner paradigm-confirming approach. The upfront research phase of a design project is critical to identify the existing knowledge benchmarks. It is essential to establish the existing knowledge, and identify where that knowledge falls short, in order to identify the gaps in knowledge that could create new value. These knowledge gaps are gateways to new knowledge white space and commercially viable new product solutions.

The concept of seeking or defining new value for business in a white space is not completely novel in itself. Business books have described the strategy of positioning products or services into a white space or blue oceans in the marketplace. One such popular theme is the *Blue Ocean Strategy* by business authors Kim and Mauborgne (2005). These authors explored the potential for a firm to seek those market spaces that have less competition, arguing that markets with cut throat competition often are bloody “red oceans” of rivals competing to the death. Seeking markets with fewer red ocean dynamics is an excellent marketing strategy of attempting to work strategically when pioneering a new product or service. However, Blue Ocean strategies are difficult to sustain, as competitors can easily copy them if the technology, identity, or business model are un-protectable.

Thus, beyond the strategic market positioning of new product offerings in those Blue Oceans with less competition, I have found that there are similar novel strategic white space positioning strategies that arise in the new product design and development process. These opportunities arise throughout the product experience by researching new value creation opportunities throughout the consumption chain, strategically seeking multiple value-creating insights that create a new competitive reality beyond the business strategy of market positioning in areas with less competition.

5.4.3 Commercial Viability is the New Product Benchmark of Competitive Advantage

Commercially viable new white space opportunities appear in the supply chain, distribution channel, business model, and even the endowed product biases of stakeholders. Designing new products into these white spaces requires diligent research into the existing consumption chain benchmarks and stakeholder preferences. Design research into this consumption chain requires designerly analysis and synthesis into the unmet insights that seek new value creation and competitive advantage by strategic design. Whilst it is not often achievable to create a 10-time better functional solution as Theil noted previously for innovation, the combination of multiple value creating differentiations arising anywhere in the consumption chain can derive sufficient combined advantages over existing product alternatives for establishing commercial viability in the marketplace. The key is to

determine what constitutes value as judged by the key stakeholders, and what amount of value will be necessary to win their business in the marketplace.

The common perception is that product cost is the primary driver. Whilst cost is a critical component and a driving economic benchmark for a designer's success in the marketplace, it is not the only factor. As explored in the article "[Creating Competitive Advantage](#)," a new product's competitive advantage is a combination of factors that can be simply expressed as raising the customer's willingness to pay and lowering the firm's opportunity cost of creating the product ([Ghemawat and Rivkin 2006](#)). In my past discussions with my teams, I would simply challenge them to seek to create the best product at the lowest cost. Whilst a new product may deliver, as Levitt would say, customer-getting benefits and at the same time lower the cost to produce, this does not necessarily mean that the market price needs to drop. A sign of customer-getting design is the willingness of the customer to pay a better price for a better design experience.

New product viability is bestowed by capturing the sale in the competitive marketplace, as Levitt is quoted as saying, "[A product is not a product unless it sells. Otherwise it is merely a museum piece](#)" (qtd. in [Károlyi 2015: 73](#)). Commercial viability is the cornerstone of new product design and development, achieved through designing customer acquisition differentiators into the new product. The level of competitive advantage bestowed by a new product design is the metric of commercial innovation and is evidenced by business viability as judged by the stakeholders in the marketplace. Attaining commercial viability is challenging in new product design, and it requires the strategic design practice described in this thesis. The highest level of this design practice is the achievement of commercial viability through designing competitive advantage, while at the same time avoiding the opportunistic short cuts that border if not cross the line of professionalism in the practice of new product design.

5.4.4 [Strategic Competitory Thinking the New Competitive Reality](#)

In the past, form and function dominated the product design stage and were often debated as a trade-off or focus on one aspect or the other. As competition drove new demands, designers responded by competitively adding functions to products that were beyond the needs of the stakeholders in a designerly "arms race" for advantage. As [Porter](#) argued, this type of strategy does not lead to an advantage if

copied by competitors. Simply adding features can lead to cost escalation, but if the consumer is unwilling to pay for the perceived design benefit, the feature adding strategy can be a trap.

In today's new product design paradigm, form and function combine at high levels of design seeking to achieve a unique design experience. The high level of product design execution we see today is taken for granted; as the competitive bar has risen and the naturally selective dynamic of the marketplace has done its work, high levels of product design have become expected by stakeholders. Performance, quality, and cost have all pushed boundaries previously thought impossible. Future design paradigms will build on these attributes as the minimum viable products, seeking to leverage a value-creating strategy designed beyond these minimum expectations.

Competition has driven this design evolution as the availability of products has expanded and stakeholders have had more than one choice for their needs. Product value expectations have far surpassed the utilitarian value of function in competitive product situations, to where function, form, and now experience are the minimum new product design requirements. The strategic process of designing beyond the form, function, and experience for creating competitive advantage in the marketplace is the future of design and the next opportunity space for designers. This strategy must inform the design process with competency insights as a method of making the correct design choices at the beginning and throughout the design process.

This exploration of past practice demonstrates that the future of design value creation must surpass the form-function-experience expectations. We are entering an era of next-level design creativity, one based on designerly strategic competitive value creation and business model design integrated into the form-function-experience stakeholder expectations. Design as strategy in commercial marketplaces is the next evolution of the designerly enquiry. This design thinking based on the differentiation by design theory, as seen in case three, is the strategic design process or the "how" of creating new competitive advantages throughout the stakeholder-product experience.

5.5 The CAM Knowledge Framework – Practice - Design - Compete

*You see things; and you say 'Why?' But I dream things that never were;
and I say, 'Why not?'*

George Bernard Shaw, *Back to Methuselah*

5.5.1 Design Projects are Different from Practice Projects

Design projects arise from technical, artistic, educational, medicine, or most all disciplines. For example, Industrial Design and Engineering are both independent disciplines, or—as Evans describes them—two distinct professions, yet they share many common elements as design does with all disciplines. Evans, in his paper “[The Development of a Design Tool to Improve Collaboration Between Industrial Designers and Engineering Designers](#),” describes the interrelationship between industrial designers and engineers as they seek to create new products in increasingly competitive commercial environments. Citing the often-conflicting nature of the industrial designer’s challenge of open-ended ill-defined problems when compared to the engineer’s well-defined challenges, Evans points to a divergence that occurs because of the nature of the challenge each profession is tasked with. (Evans 2009). This divergent focus, yet interdependent relationship, is the essence of the practice-design symbiotic relationship explored and explained in this research.

In practice, practitioners rely on the established knowledge and skills of their paradigm to solve problems in a disciplinary recitation of existing knowledge, whilst design co-exists as an interdisciplinary discipline arising in practice, when the existing knowledge of practice falls short. For example, in practice the engineer would be given the requirements, analyse the data, and create the specifications for the project utilizing best-practice skills to engineer the solution from the existing knowledge paradigm, relying on the certainty of established practice. However, if an engineer were to encounter a challenge where the existing knowledge solution fell short, the only productive choice the engineer would have is to design and pioneer a new knowledge pathway for a successful solution; in this modality of creative action the engineer transforms into a designer of new engineering practice.

A designer is often a practitioner (engineer, industrial designer, doctor, etc.) pressed into the design role from a functional disciplinary background. Building on their disciplinary knowledge, practitioner-designers pursue new knowledge by drawing upon designerly forms of enquiry and skillsets beyond their knowledge of their disciplinary skills. Designerly skills seek to re-frame, interpret, and identify the

unmet needs of the problem as discussed in detail in Chapter 4, often seeking creative solutions to fill the knowledge gap at hand. Quite often, the practitioner-designer must reach out of the core discipline in a knowledge-pioneering challenge that is a designerly quest for new knowledge. This ability to cross disciplines, or rise out of a disciplinary knowledge skillset and successfully create new solutions, is a telling characteristic of an experienced, proficient designer-practitioner. As Fuller says, “*A designer is an emerging synthesis of artist, inventor, mechanic, objective economist and evolutionary strategist.*” I would add to this in the quest for seeking, conceiving, and creating new knowledge.

In commercial new product design and development, the design projects weave in and out of practice projects, employing designerly methods of new knowledge creation and strategically incorporating the best practices from a number of disciplinary knowledge bases when creating the new knowledge solution. This dialectic model of practice is the iterative evolution of how ideas become actionable objectives and potentially viable design alternatives to the existing solution knowledge. Once a product is designed, the design experience is not over as the new design must be productised and commercialised through a pathway of continuous competition with the existing stakeholder solutions. As this study has discussed, these competitive challenges arise beyond functional performance in the marketplace, as stakeholders in the marketplace are the ultimate judges of design value and advantage.

The chart below (see Table 5-1) illustrates the differences between a practice project process and a design project process; although intertwined in practice they are separate here for clarity of the different heuristics and skill sets.

DIFFERENCE BETWEEN DESIGN AND PRACTICE

DESIGN PROJECTS	PRACTICE PROJECTS
Multi-disciplinary approach to problems	Disciplinary approach to problems
Reframing the rules	Following the rules
Potential for innovation	Potential for optimization
Original creations for problem solving	Copies of past problem solving
Seeks opportunity to create new value	Seeks to optimize existing value
Lacks an explicit roadmap	Follows an explicit roadmap
Design creates new solutions	Practice optimizes existing solutions
Divergent-convergent thinking process	Convergent thinking process
Often ambiguous, lacks a past example or roadmap	Built on certainty of past practices and roadmaps
Continually researching the needs to develop requirements	Relying on stated requirements based on pre-existing practice
Heuristic based decision-making	Knowledge based decision-making
Re-focuses on the ¼" hole	Focuses on the ¼" drill
Paradigm changing focused	Paradigm confirming focused
Quest for new knowledge	Practice of existing knowledge

Table 5-1: Design Project - Challenge Versus Practice Project-Challenge Comparison²

² The ¼" hole reference refers to the Levitt quote "*People don't want quarter-inch drills. They want quarter-inch holes.*"

5.5.2 The Practice Knowledge Cycle Model

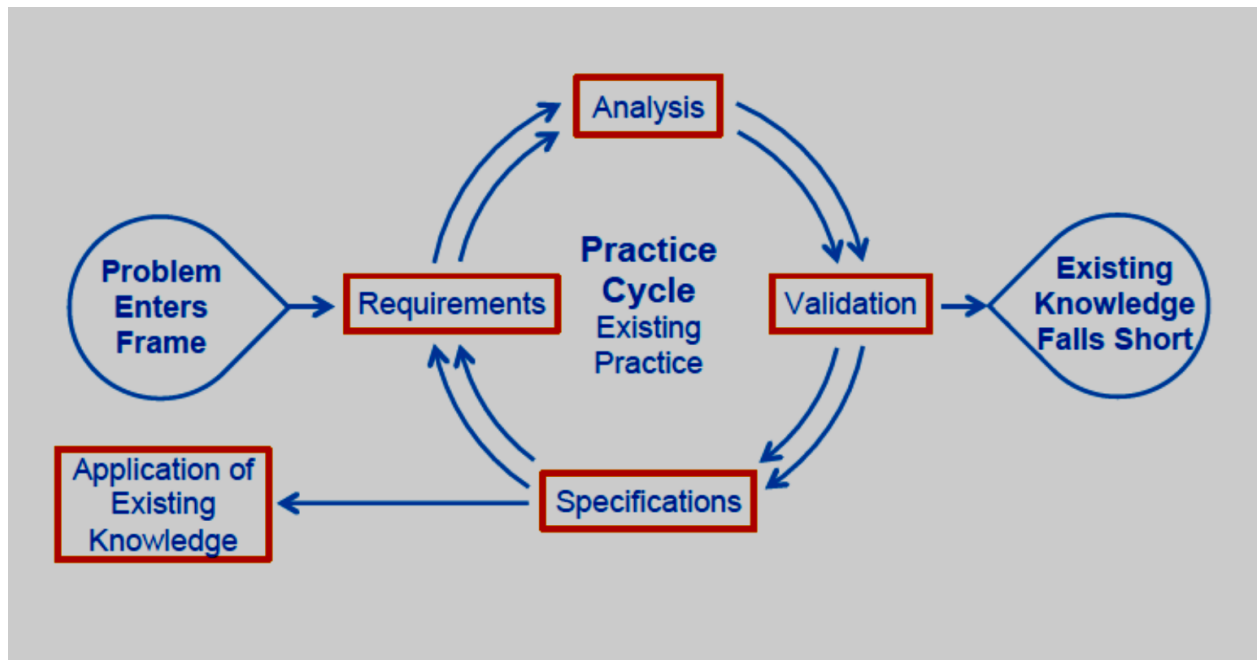


Figure 5-2: The Practice Knowledge Cycle

When existing knowledge of practice is sufficient to solve the problem

- Problems enter the process
- Practitioner reviews the problem requirements
- Practitioner analyses the requirements and reflects on the challenge
- Practitioner relies on existing best practice knowledge for crafting a solution
- Practitioner validates the solution to confirm that it conforms to the requirements
- Practitioner develops the specifications for the solution to be implemented

When existing knowledge of practice is insufficient to solve the problem

- Practitioner reviews the problem requirements
- Practitioner analyses the requirements and proposes a solution
- Practitioner validates the solution and determines he cannot meet the requirement
- Practitioner cannot solve the problem as a knowledge gap exists
- Practitioner must abandon the effort or attempt to seek new knowledge creation
- The practitioner must become a practitioner-designer and enter a design process

In new product development from the case histories, the new knowledge challenge appeared in each case as a knowledge gap where the existing knowledge fell short. This knowledge gap presented a challenge for seeking a new knowledge solution where the existing solutions were not adequate. In 1973, Rittel and Webber characterised these design challenges as “wicked problems”, an appropriate and relevant description of what practitioners face when confronted with a knowledge gap in practice. A knowledge gap exists when there is insufficient existing knowledge of practice to get the objective accomplished. In commercially competitive markets, this gap often represents the new value propositions the business is seeking to create and bring to market, the wickedness of the challenges arises from the complexity of the interplay of the many factors often unseen that contribute to the failure and success of the efforts.

These wicked problems and their lack of existing knowledge solutions are the essence of what separates a design project from an existing practice project. A traditional practice project would have the needs and requirements articulated by the apparent challenge at hand, as well as a previous history of successful solutions in past practice. Kuhn stated in referring to existing knowledge problems, “The man who is striving to solve a problem defined by existing knowledge and technique is not, however, just looking around. He knows what he wants to achieve, and he designs his instruments and directs his thoughts accordingly” (Kuhn 1970: 96). Based on my experience in practice, much of my time involved solving problems defined by existing knowledge solutions; the most challenging circumstances were always the pursuit of new knowledge. The proficient pursuit of new knowledge in a disciplinary practice may well be the benchmark for expertise in practice.

When practitioners do venture into the challenge of design, they find that the approach to the projects often must change from a paradigm-confirming (defined by existing knowledge) to a paradigm-changing (defined by the quest for new knowledge) design project. This designerly enquiry by nature requires strategically focused research into the front-end problem definition and need-finding often referred to as “the fuzzy front end” of those wicked new knowledge problems. This is the territory of design proficiency, starting with a practitioner-designer seeking new competency knowledge solutions by employing designerly forms of enquiry.

5.5.3 The Design Knowledge Creation Cycle Model

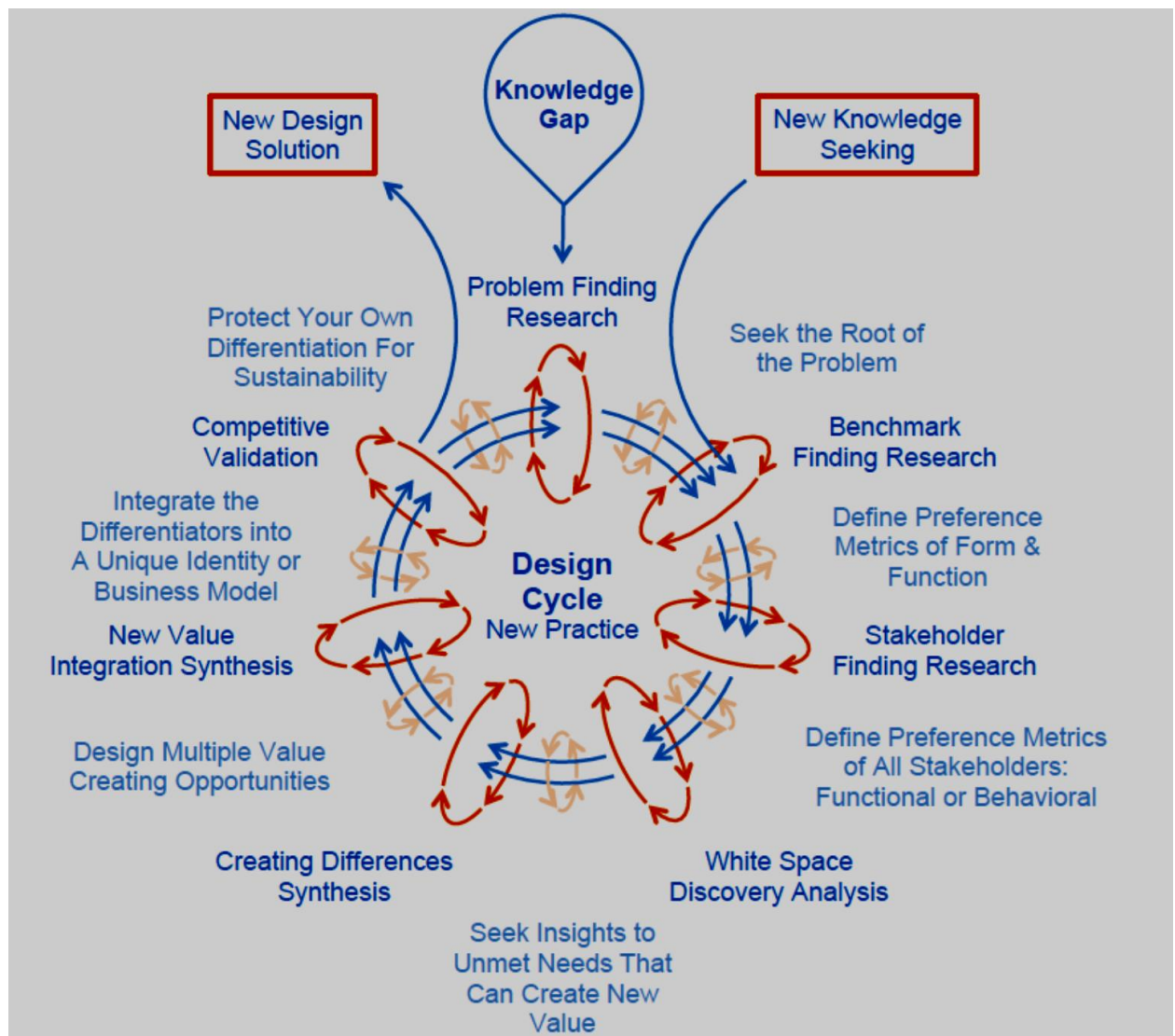


Figure 5-3: The Design Knowledge Cycle and Heuristics of the Design Process

Design Process Begins When the Existing Knowledge of Practice Falls Short

When the existing knowledge of practice falls short and the problem remains, there is a knowledge gap exposed. When engaged in a solution-seeking pursuit, the practitioner must transmute paradigms from practitioner to designer and embrace the uncertainty of a heuristic designerly quest strategy to resolve the problem. Utilizing the designerly heuristics of enquiry discussed in Chapter 4, practitioner-designers seek, conceive, and create a new a competitive knowledge solution that addresses this knowledge gap of practice.

5.5.4 Practice and Design Co-Exist in a Practice-Design Model

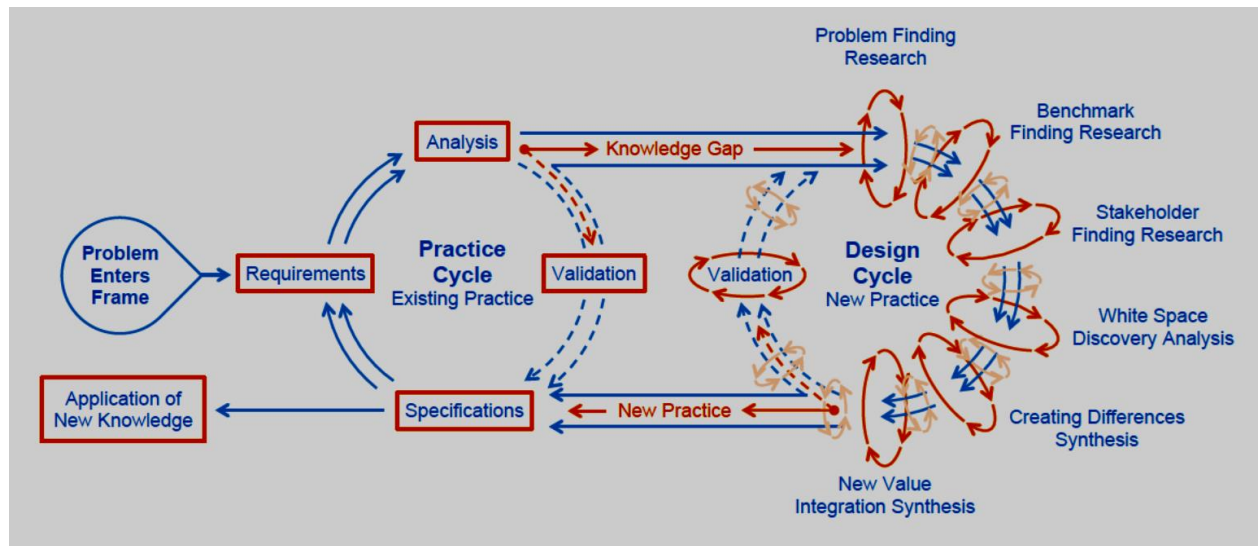


Figure 5-4: The Practice – Design Co-Existent Relationship – Creating New Knowledge

The Practice – Design Interaction Co-Exists in Practice

This practice-design cycle is how new knowledge of practice is created by design interactively in a practitioner's work. Quite often, the design of new knowledge requires a significant amount of research as outlined in Chapter 4, where the heuristics of creative problem-solving are engaged and made explicit, seeking those unexplored white spaces. Design work is a rigorous, research-driven process; it often falls short, but designerly enquiry can raise the certainty of a success. New propositional knowledge may not be practical or better than the existing solutions. Simply being new does not make the knowledge useful or applicable to the problem at hand. There is a range or spectrum of what is competency new knowledge versus new knowledge that does not compete. Thus, the practice-design propositional knowledge creation must compete with the existing paradigm of knowledge, in order to validate that the new knowledge is in fact advantaged or superior.

The applicability of a new knowledge proposition is judged by how the new knowledge compares to or competes with the existing knowledge of practice. Therefore, to judge the new knowledge applicability and value as a new problem solver, the new knowledge competes for acceptance and validation by the stakeholders of the paradigm. This competition is necessary to challenge the existing paradigm's knowledge and, as [Kuhn](#) described in his work, there is often a resistance of the paradigm's stakeholders to change. ([Kuhn 1970](#)).

5.5.5 New Design Competitory Dynamic Model

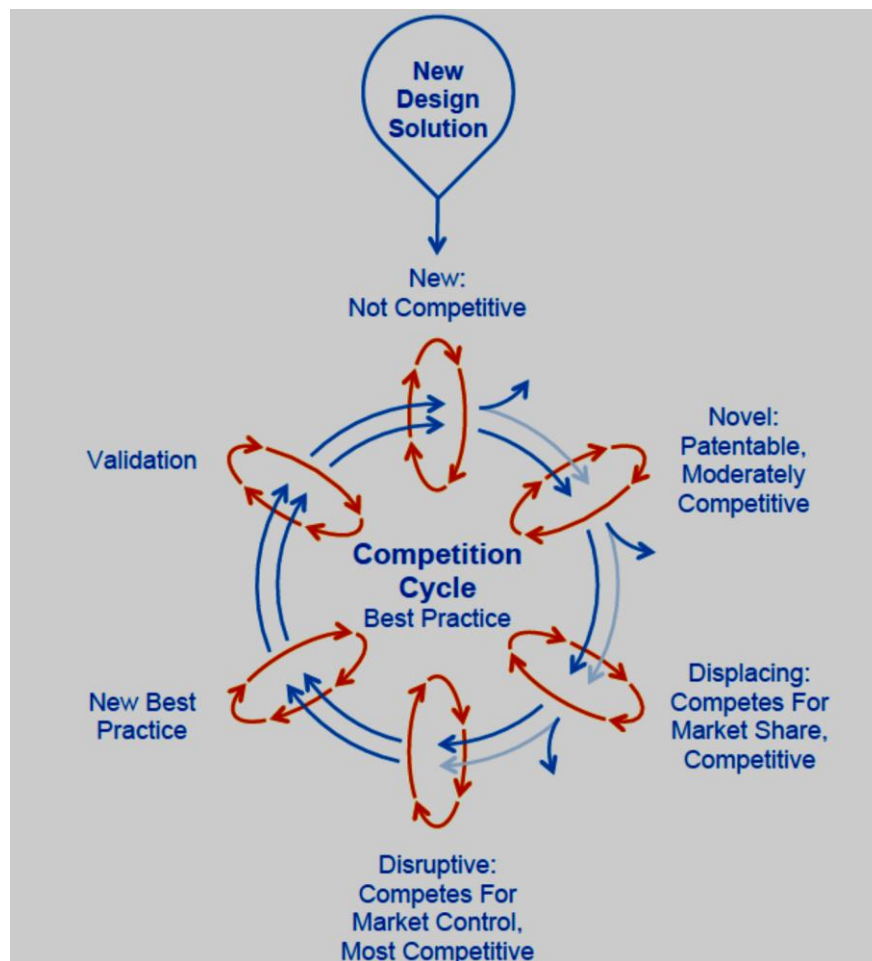


Figure 5-5: The Recognition That Not All Newly Designed Knowledge is Competitive

How new knowledge competes determines if it can be judged as innovative

Newly designed knowledge can be new, novel, incremental, moderate, or disruptive to an existing paradigm of knowledge. When new knowledge competes and is adopted by the paradigm's stakeholders, it is a sign of competitive advantage over the existing solutions. The amount of competitory ability correlates to the level of competitive advantage. In a dynamic interplay, the strength of the existing knowledge is its ability to withstand challenges from new knowledge propositions. Recognizing that change takes time for the stakeholders to release their existing endowed relationships in favour of a more competitive, new knowledge proposition, the strength of a new knowledge proposition is its speed of overtaking when competing with the existing knowledge in practice. New knowledge that displaces existing knowledge will become the new best practice knowledge of the paradigm. A dynamic relationship is expressed by this model for how new product design competes in the marketplace.

5.5.6 The Competitory Action Model as a New Knowledge Framework

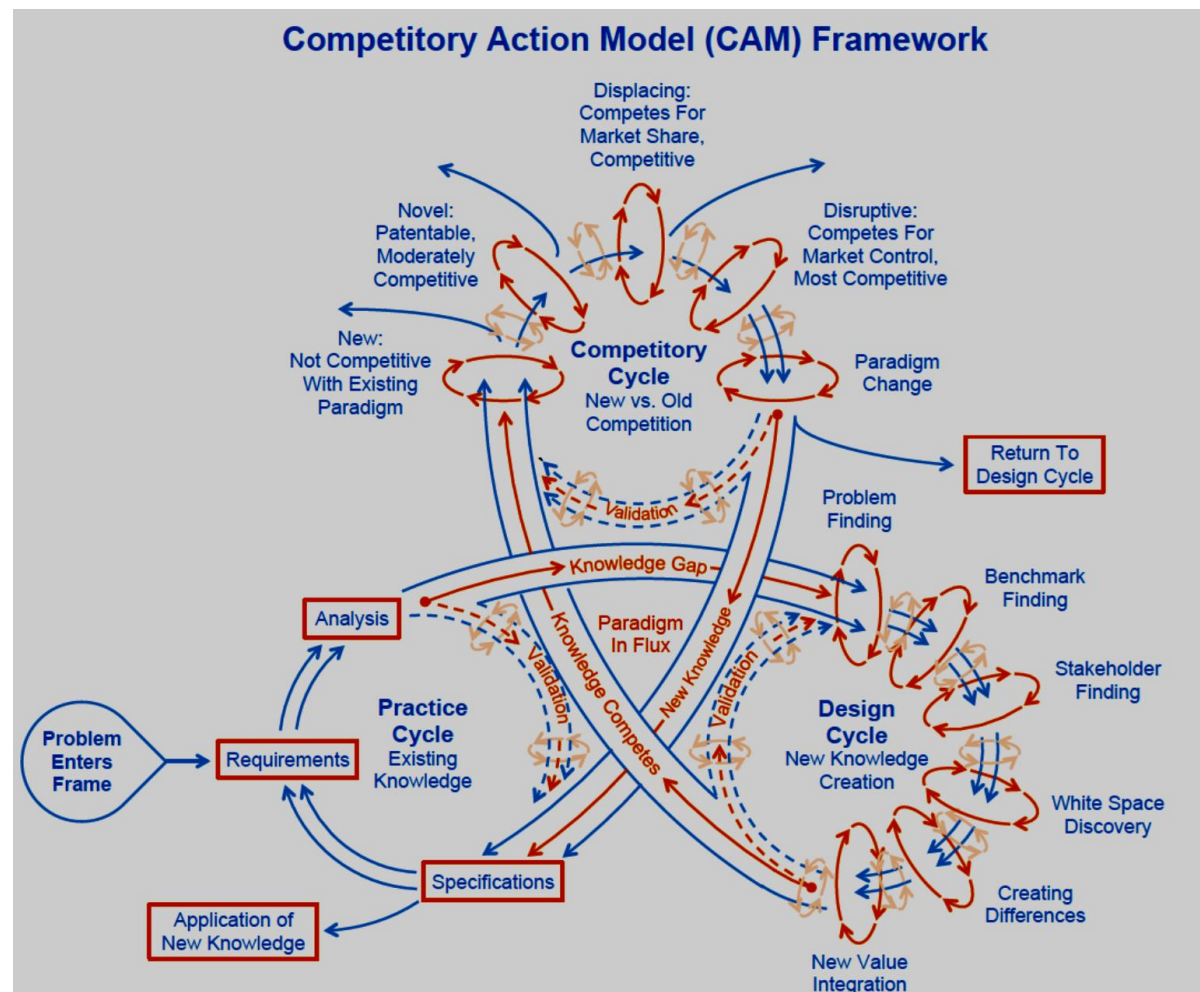


Figure 5-6: Competitory Action Model (CAM) – Creating New Knowledge (Author)

1. Problem enters Practice Cycle and, if it has a known solution, follows the existing best practice pathway to solution.
2. Problem exists, Practice Cycle completed, this is disciplinary practice.
3. If the problem cannot be solved by existing knowledge, there is a knowledge gap. The practitioner must decide to abandon or design a new solution.
4. When a knowledge gap occurs, the problem proceeds to Design Cycle.
5. There the problem follows the heuristic process of design enquiry, creating a new set of propositional solutions that are validated in the design process.
6. Once designed, the new propositional knowledge must then compete with existing best practice in a Competition Cycle to establish its value.
7. The design is judged by the paradigm stakeholders on how it competes with the existing knowledge solutions in a competition cycle of judgement.
8. Competitively advantaged, new designed knowledge captures stakeholder preference and displaces the existing knowledge solution within the paradigm.
9. The new knowledge can disrupt the paradigm and become the new best practice until another unsolvable problem challenges that best practice.
10. The knowledge creation cycle will then recycle as the new unsolvable problem and a new knowledge gap appears and the cycle repeats itself.

As with all functional specialty meanings, the addition of “new product” to design demands the meaning to include the “competitive dynamic of products” for the design knowledge creation process of design. New product design must now compete in the marketplace of existing product options. This competition requires that the new knowledge/design aspect of the new product design process not only create something new, but something new that adds value for the stakeholders who collectively judge the new product based on the competitive advantages it offers.

Product design perpetuates a continually rising bar for designers as the commercial competitive evolutionary model of competition fuels it. The conundrum for designers is that the designs must seek the most competitive position possible in the design process, but as this stakeholder expectation bar continues to rise in markets, the opportunity for differentiation decreases. Seeking competitive differentiation requires product designers to expand the existing knowledge domains as they seek to identify opportune insights for new knowledge creation. Whilst this methodological approach is itself a business advantage, the real strength of this differentiation by design process for businesses is the integration of Design Thinking philosophy based on this Differentiation by Design® heuristic enquiry into their organizational cultures.

Kuhn researched existing knowledge states, new knowledge propositions, and the way in which new knowledge changes existing knowledge paradigms in his book the *Structure of Scientific Revolutions* (1970). Building on a similar principle to explain how new design knowledge propositions are created to compete with existing product-market paradigms for product pre-eminence, I rely on the Kuhn logic. Whilst Kuhn’s model explains paradigms of science, this model explains the paradigm of the competitive product marketplace, arguably a much faster moving environment than the new academic knowledge space.

Extending this comparison, I am arguing that stakeholder shift in preference is how that newly designed knowledge competes with the pre-existing stakeholder-endowed preferences. Specifically, the competitive advantage created by newly designed knowledge is the quantitative metric of innovation, as judged by the mostly qualitative stakeholder behaviours and preferences of the paradigm. The practice-design-compete graphic above illustrates the summary of findings in a new Competitory Action Model (CAM) framework.

5.6 Contributions of the Research

Design is an epiphany of theory built on a symphony of practice, a design ethos transcending form and function while not neglecting it.

Dan Brown, “The Designers’ Ethos”

Design creates new value and competitive advantage in new product development when product developers confronted with a knowledge gap in practice, must seek new knowledge of practice to fill the gap where the existing knowledge of practice has fallen short of the development objective. This new knowledge creation quest is the designerly process of seeking, conceiving and creating product differentiation by design, skilfully employing the designerly process heuristics of a proficient designer. This competency strategic design process, explained diagrammatically in the CAM framework, builds on the recognition that all practitioners can develop this designerly proficiency, becoming designers on an exploratory quest for new knowledge when the existing knowledge of practice falls short.

It is important to recognise that not all practitioners have the same designerly motivation to embark on a design quest in their practice. Although all have the ability to develop these skills and proficiencies if they choose to invest themselves in learning the designerly process of enquiry: seeking (research), conceiving (analysis), creation (synthesis) and validation (competitory strategy). Employed with disciplinary rigour, these underlying principles of a designerly practice, this critical skill set for new product designers is the foundation knowledge of design as its own independent discipline.

5.6.1 Summary of New Knowledge Contributions

- The first contributory insight is the explanation that design projects and practice projects are fundamentally different praxes, yet co-dependent and symbiotic. Practice is fundamentally a disciplinary knowledge-confirming process, and design is by nature a disciplinary knowledge-creating process. This insight argues that design is how humans seek, conceive, and create new knowledge. Practice is how humans engage in the activities of an existing discipline's knowledge (Establishing a new meta-definition basis for design, see 5.5.2).
- The second contributory insight is the explanation that a practitioner will approach practice with the existing knowledge of the discipline, employing best practices addressing the challenge at hand. At times, the practitioner finds him- or herself in the circumstance where the existing knowledge of practice falls short of resolving the situation. A knowledge gap appears; the proficient practitioner becomes a practitioner-designer in the pursuit of a resolution to the situation, employing designerly heuristics and methods in his quest.
- The third contributory insight argues that design is an independent discipline with its own disciplinary principles of enquiry and heuristics of praxis. This independent branch of knowledge contains designerly methods and heuristics as the disciplinary knowledge base. While traditional academic disciplines focus on a paradigm-conforming praxis, design mobilises the paradigm-changing praxis for exploring and creating new knowledge within a discipline.
- The fourth contributory insight argues that in new product design, a competency "white space" strategy is required to focus this designerly quest. Competitory white space research engages designerly enquiry as a focused pursuit of competitive advantage within the marketplace. New products compete with existing products to validate an advantage with the stakeholders. Those products that achieve competency success become the new expectation benchmarks of the stakeholders within their market segment.
- The fifth contributory insight is an explanatory Competitory Action Model (CAM). CAM is a diagrammatic framework, explaining the practice-design-competite dynamic as competency new knowledge creation theory. This framework graphically expresses the dynamic interrelationship of how new knowledge propositions, stemming from knowledge gaps, challenge existing knowledge to compete for the knowledge dominance of the paradigm.
- The sixth contributory insight explains the meaning of innovation created by design in existing commercial marketplaces, emphasizing that the creation of competitive advantage is the metric for commercial new product innovation (Establishing a new meta-definition basis for innovation, see 5.5.2).

5.6.2 Semantic Contributions of this Research

The methods and findings of this research required an analysis and refocus of the meta-definitions of design and innovation in order to enable the exploration and investigation of the new product design process for this research. This thesis argues that the Design Methodology and Scientific Method of enquiry co-exist in the practice of how humans seek new knowledge. Other forms of knowledge creation (serendipity, revelation, tradition, etc.), were not investigated as part of this research question that focused on how product design creates value and competitive advantage in markets.

- The seventh and eighth contributions address the common meta-definition of design and innovation that were necessary for research (see Chapter 2).

Design is how humans, seek, conceive, and create new knowledge.

Innovation is when new knowledge achieves competitively advantaged outcomes over the existing knowledge.

5.6.3 Methodological Contributions

- The ninth contribution of this research presents a model for a reflective-practice-led research methodology for investigating the design process of one's own practice as detailed also in Chapters 1 and 3 and as explained in section 5-7.
- The tenth contribution of this research presents a thesis research methodology of using case histories of successful new product development practice that have a positive confirmation bias based on competitory market success. Based on a mixed methods approach for data research and analysis, case histories can provide historical market, design, and patent records as quantifiable sources of information in support of the academic research of new product design and development praxes.

5.7 Limitations of the Research

Opportunity is missed by most people because it is dressed in overalls and looks like work.

Anonymous

This doctoral thesis presents a theoretical CAM framework for new product design and development. My new theory derives from reflective and abductive logical enquiry of the researcher's past practice. As with all studies, however, one must view the confidence in the findings from a perspective of the limitation of one study. Further empirical research applying the CAM framework and designerly heuristics of enquiry in this study in a systematic action-research process would advance the applicability of the framework and process model in practice and research.

Practical implications – This work offers insights for designers who wish to create new products to compete in competitive markets. Specifically, the heuristics and CAM Framework in this study can assist designers working for SMEs in creating not only new products that address a form or function challenge, but build off this focus in the creation of competitively advantaged new product knowledge. This process is based on a differentiation by design focus on value creators that arise throughout the product's consumption chain. Additionally, this work provides a potential research protocol for the study of one's own practice for other researchers.

Originality/value – Much of the existing research in new product design has focused on form, function, design skills, and design processes for the creation of new products. This research builds on the previous work by integrating the strategic competency focus of creating competitive advantage into the study. New product value creation beyond form and function is not only necessary for competitive position in the marketplace; it is the proficient practitioner-designer who is in the greatest position to influence its creation.

Furthermore, studies in the area of creating competitive advantage in business have concentrated on large enterprises, with researchers analysing historical cases of large organizational success as opposed to SMEs. This thesis fills this gap by presenting an explanatory model of the strategic design process, as a new product development framework, that SMEs can learn from when pioneering a new product into a competitive marketplace.

5.8 Next Steps for Future Research

People don't want quarter-inch drills. They want quarter-inch holes.

Theodore Levitt

This research has taken a less-travelled academic path in Design by studying the practices of a mature researcher through studies of one's own practice. Having completed the explanatory research of this process, and at the same time establishing an academic knowledge base to compliment my practice knowledge of design, I believe that there is much to learn in this discipline through the academic research of practice. The designerly heuristics and CAM theory presented offer a framework for further practice-led research of the design process, through either Action Research, or Reflective Practice Research.

Creating an academic design research pathway for experienced practitioners offers a unique opportunity to capture that tacit knowledge of practice through explanatory research. Whilst it is more common to research the exploratory process in an academic setting, it is not as common to research the exploratory process of practice that competed in the marketplace. Although there is much to learn about the process of how designers create new knowledge in competitive situations, as well as how academics approach this research in the designerly quest to create new theory.

Beyond the extension of this new theory into the paradigm of design practice, other opportunities may present themselves to conduct research utilizing the CAM Framework in the disciplinary examination of other knowledge-creation paradigms. Below I have suggested some CAM Frameworks in the context of other disciplines (See Figure 5-7). This suggests the possibility of a shared competitive dynamic and relationship theory for explaining paradigm change within other disciplines.

This research of a design practice identified many methods and heuristics of the design process, which I have recognised share similarities with the academic research process. An intriguing question presents itself: what is the relationship between design as defined in this thesis and all research? Ironically, there is a synergy of shared philosophies, logical constructs, methodologies, paradigms, and possibly CAM Frameworks in creating new academic knowledge in both practice and theory. Future studies to pursue these questions through additional academic research of the similarities of design process (exploratory) and academic research

(explanatory) as the co-existent processes of new knowledge creation are encouraged.

5.8.1 Further Research Pathway One

Utilizing the design heuristics outlined in Chapter 4, further Action Research to test the designerly process presented herein, I can envision several variations of this type of study:

1. Action research of a new product design study that reproduces a previous action research study for new product design. For example: a researcher attempts to follow a previous thesis, but actively deviates from that study through the incorporation of the research heuristics with a competency focus as outlined in Chapter 4, structuring a before and after comparison of the design outcomes that can be measured.
2. Action research of a new product design on behalf of a commercial client to create a product that would compete in the marketplace. Market-focused new product design, integrating a traditional research protocol and a client in a combined practice-academic immersion experience.
3. Action research centred on the classroom experience of teaching the differentiation by design process, allowing the students to form teams and utilising previous design projects. Introducing the DxD design pedagogy and having them reproduce their designs in light of the heuristics described in Chapter 4.
4. Action research conducted in the marketplace where an existing organization's design team is further educated and trained in the differentiation by design process, and an assessment methodology designed to assess if there were any changes in the team's performance or design culture after exposure to the heuristics.

5.8.2 Further Research Pathway Two

A possible second track of future research could emerge from the Competitory Action Model of the product design and development process. Using the CAM

framework there may be possible applicability to other forms of knowledge creation and transfer. Below, I have briefly outlined a few models that at first glance appear to fit the logic and mapping of this framework. Without warrant, I support this opportunity to examine the framework in the context of other applications.

Competitory Reflective Paradigm Change Frameworks

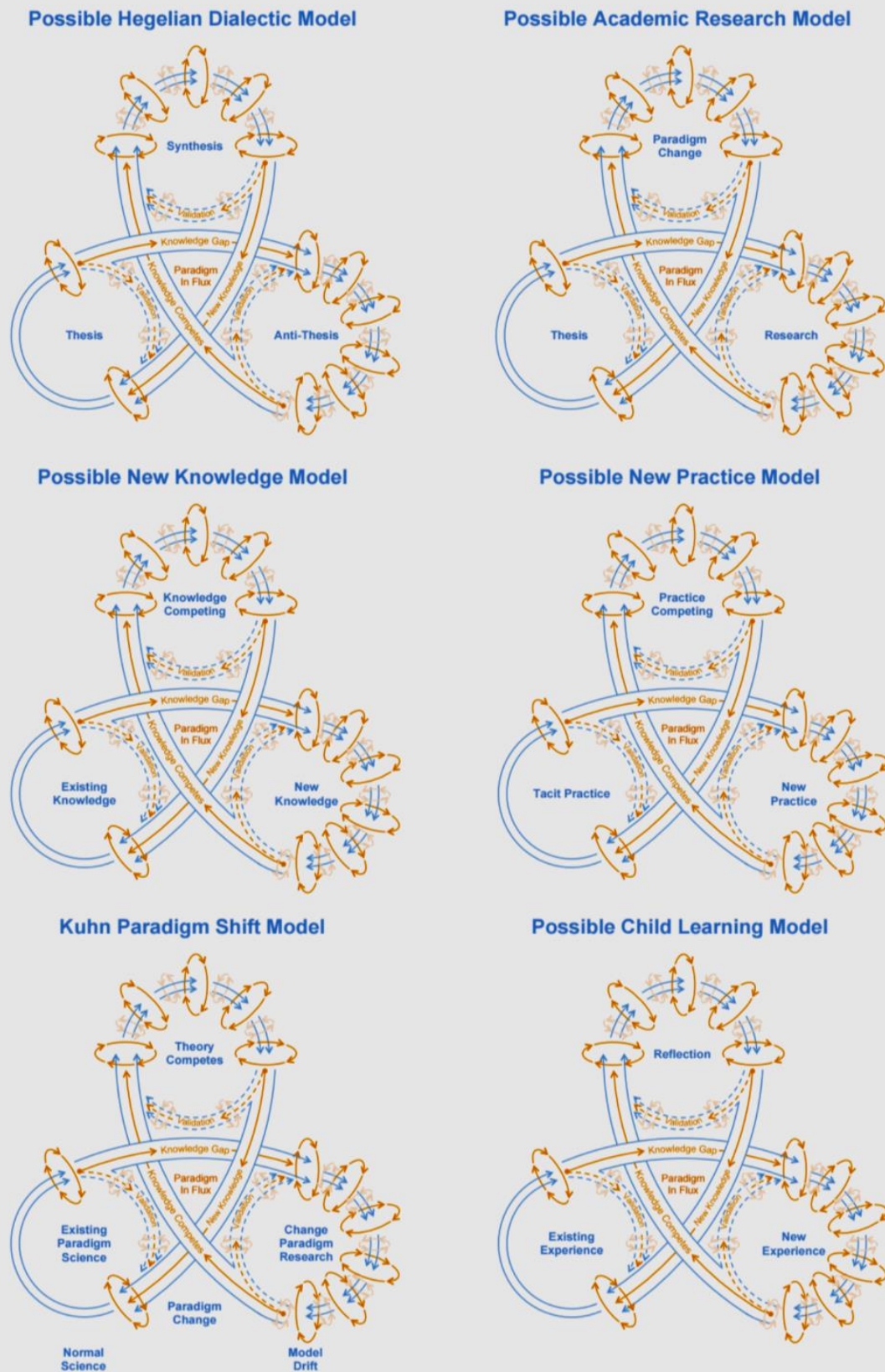


Figure 5-7 Possible Applications of the CAM Frameworks for future Research

5.9 Concluding Remarks

A skilful man reads his dreams for self-knowledge, yet not the details but the quality.

Ralph Waldo Emerson

In commercial markets, at least in the U.S., business leaders are embracing a design thinking new-value creation philosophy for business. From my experience, the consensus on what design thinking is or how it functions in the creation of new value has yet to be researched, analysed, and explained adequately. Having competed in markets for 35 years and pursued many commercially viable new-product challenges, I agree with the consensus that it is design that will anchor competitive advantage creation in the future, although I am concerned with the bandwagon euphoria of the design thinking movement and its many cheerleaders parading Design Thinking.

From my perspective, there is a bit of a false prophet mythology around design thinking today, prophesiers who claim that design thinking is somehow this new saviour for business, without having practiced or researched the design process. These are effectively false prophets of design without the comprehension of what they are preaching, perpetuating a shallow mythology, versus the reality or the evidence-based rigour of the design process. As designers, we must actively engage to confront this bandwagon through the education of our peers in business and academia.

The challenge for designers remains. Will design thinking rise and fall as many of the fads that business strategists championed in the past? Alternatively, can we organise as a discipline, centred on the designerly form of enquiry that is, in my opinion, the core ontology of our discipline? Will we seize this moment to establish a base of knowledge acknowledged and sanctioned by the Academia community, and necessary for formally legitimizing design as an independent academic discipline?

There is a more evolved academic acceptance of design as a discipline in other parts of the world than in the U.S., as in the U.K., where I am pursuing this academic research journey. As many design thought leaders have stated previously, I strongly support further research partnerships by experienced academic researchers and practitioners seeking academic qualifications, who would work together to develop the explanatory theory of the exploratory design practice, in support of an independent design disciplinary knowledge base that would anchor a designerly core pedagogy and discipline.

List of References

- Archer, L. B. (1995) 'The Nature of Research'. *Co-Design: Interdisciplinary Journal of Design and Contextual Studies* 2, 6–13 [online]. available from <<http://www.metu.edu.tr/~baykan/arch586/Archer95.pdf>> [25 August 2014]
- Archer, L. B. (1992) 'The Nature of Research into Design and Design Education'. in *The Nature of Research into Design and Technology Education*. ed. by Archer, B., Baynes, K., and Roberts, P. [online]. Loughborough: Loughborough University, 7–14. available from <<https://dspace.lboro.ac.uk/2134/1687>> [4 September 2015]
- Archer, L. B. (1979a) 'Whatever Became of Design Methodology?' *Design Studies* 1 (1), 17–18
- Archer, L. B. (1979b) 'The Three Rs'. *Design Studies* 1 (1), 18–20
- Archer, L. B. (1965) *Systematic Method for Designers*. London: Council of Industrial Design
- Ariely, D. (2010) *Predictably Irrational: The Hidden Forces that Shape Our Decisions*. Rev. edn. New York: Harper Perennial
- Armour, K. and Chen, H. (2012) 'Narrative Research Methods: Where the Art of Storytelling Meets the Science of Research'. in *Research Methods in Physical Education and Youth Sport*. ed. by Armour, K. and Macdonald, D. London: Routledge, 237–49
- Barr, R. E. (1947) *Woodpecker Drill*. United States Patent US 2,424,138
- Benson, C. L. and Magee, C. L. (2015) 'Quantitative Determination of Technological Improvement from Patent Data'. *PLoS ONE* 10 (4), e0121635
- Brooks, W. R. and Heinzl, I. C. (1978) *Purgeable Dispensing Gun for Polyurethane Foam and the Like*. United States Patent US 4,117,551
- Buckminster Fuller Institute (n. d.) *Big Ideas* [online] available from <<https://www.bfi.org/about-fuller/big-ideas>> [7 December 2016]
- Buede, D. M. (2009) *The Engineering Design of Systems: Models and Methods*. 2nd edn. Hoboken, NJ: Wiley
- Carroll, J. M. and Rosson, M. B. (2005) 'A Case Library for Teaching Usability Engineering: Design Rationale, Development, and Classroom Experience'. *Journal on Educational Resources in Computing (JERIC)* 5 (1), article 3
- Case, J. M. and Light, G. (2011) 'Emerging Methodologies in Engineering Education Research'. *Journal of Engineering Education* 100 (1), 186–210
- Charmaz, K. (2006) *Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis*. London: Sage Publications
- Christensen, M. C and Cook, S. (2005) *Marketing Malpractice the Cause and the Cure*. Boston, Harvard Business Review December 2005

- Cooper, R. G. (1990) 'New Products: What Distinguishes the Winners?' *Research Technology Management* 33 (6), 27–31
- Coumans, A. (2003) 'Practice-led Research in Higher Arts Education'. in *On the Move: Sharing Experience on the Bologna Process in the Arts*. ed. by Ophuysen, T. and Ebert, L. Amsterdam: ELIA, 62–67
- Cross, N. (2011) *Design Thinking: Understanding How Designers Think and Work*. London: Bloomsbury Academic
- Cross, N. (2007) 'From a Design Science to a Design Discipline: Understanding Designerly Ways of Knowing and Thinking'. in *Design Research Now: Essays and Selected Projects*. ed. by Michel, R. Basel, Switzerland: Birkhäuser, 41–54
- Cross, N. (1999) 'Design Research: A Disciplined Conversation'. *Design Issues* 15 (2), 5–10
- Cross, N. (1982) 'Designerly Ways of Knowing'. *Design Studies* 3 (4), 221–27
- Dahlin, K. B. and Behrens, D. M. (2005) 'When Is an Invention Really Radical? Defining and Measuring Technological Radicalness'. *Research Policy* 34 (5), 717–37
- Dewey, J. (1938) *Logic: The Theory of Enquiry*. New York: Henry Holt
- Dewey, J. (1929) *The Quest for Certainty: A Study of the Relation of Knowledge and Action*. London: George Allen & Unwin Ltd.
- Dewey, J. (1922) 'The Nature of Aims'. in *Human Nature and Conduct: An Introduction to Social Psychology*. New York: Modern Library, 223–37
- Dewey, J. (1916) *Democracy and Education: An Introduction to the Philosophy of Education*. New York: Macmillan
- Dorst, K. (2010) 'The Nature of Design Thinking'. Eighth Design Thinking Research Symposium. held 19–20 October 2010 in Sydney, Australia. available from <http://bbcdcomdes.weebly.com/uploads/1/1/8/6/11866691/dtrs8_proceedings.pdf> [7 December 2016]
- Evans, M., Pei, E., and Campbell, R.I. (2009) 'The Development of a Design Tool to Improve Collaboration between Industrial Designers and Engineering Designers'. in *Proceedings of the Eighth European Academy of Design International Conference* [online] held 2009. 161–165. available from <<https://core.ac.uk/download/pdf/7433076.pdf>> [15 December 2016]
- Fagerberg, J. (2003) 'Schumpeter and the Revival of Evolutionary Economics: An Appraisal of the Literature'. *Journal of Evolutionary Economics* 13 (2), 125–59
- Flyvbjerg, B. (2006) 'Five Misunderstandings About Case-Study Research'. *Qualitative Enquiry* 12 (2), 219–245
- Friedman, K. (2008) 'Research into, by, and for Design'. *Journal of Visual Arts Practice* 7 (2), 153–60

- Friedman, K. (2003) 'Theory Construction in Design Research: Criteria: Approaches, and Methods'. *Design Studies* 24 (6), 507–22
- Friedman, K. (2000) 'Creating Design Knowledge: From Research into Practice'. IDATER 2000 Conference [online]. Loughborough: Loughborough University. available from <<https://dspace.lboro.ac.uk/2134/1360>> [4 September 2015]
- Fuller, R. B. (1971) *The World Game: Integrative Resource Utilization Planning Tool*. Carbondale, IL: World Resources Inventory, Southern Illinois University
- Getzels, J. W. and Csikszentmihalyi, M. (1976) *The Creative Vision: A Longitudinal Study of Problem Finding in Art*. New York: Wiley
- Ghemawat, P. and Rivkin, J.W. (2006) 'Creating Competitive Advantage'. *Harvard Business School* 9-798-062
- Godin, B. (2015) *Innovation Contested: The Idea of Innovation over the Centuries*. New York: Routledge
- Guba, E. G. and Lincoln, Y. S. (1981) *Effective Evaluation: Improving the Usefulness of Evaluation Results Through Responsive and Naturalistic Approaches*. San Francisco: Jossey-Bass
- Hahn, C. (2008) *Doing Qualitative Research Using Your Computer: A Practical Guide*. London: Sage Publications
- Hatchuel, A., Le Masson, P., and Weil, B. (2004) 'C-K Theory in Practice: Lessons from Industrial Applications'. Eighth International Design Conference. held 18–21 May 2004 in Cavtat, Dubrovnik, Croatia. available from <https://www.designsociety.org/publication/39/ds_32_proceedings_of_design_2004_the_8th_international_design_conference_dubrovnik_croatia> [7 December 2016]
- Hatchuel, A. and Weil, B. (2009) 'C-K Design Theory: An Advanced Formulation'. *Research in Engineering Design* 19 (4), 181–92
- Holmström, J., Ketokivi, M., and Hameri, A. (2009) 'Bridging Practice and Theory: A Design Science Approach'. *Decision Sciences* 40 (1), 65–87
- Insta-Foam Products (1985) Sales Sheet. Platteville, WI: Insta-Foam Insulation & Roofing, LLC
- Jarvis, P. (1999) *The Practitioner-Researcher: Developing Theory from Practice*. San Francisco: Jossey-Bass
- Károlyi, L. (2015) *Business Chameleon: A Practical Guide to Success for Managers*. Bloomington, IN: iUniverse
- Kim, W. C. and Mauborgne, R. (2005) *Blue Ocean Strategy: How to Create Uncontested Market Space and Make the Competition Irrelevant*. Boston: Harvard Business School Press
- Kolko, J. (2010) 'Abductive Thinking and Sensemaking: The Drivers of Design Synthesis'. *Design Issues* 26 (1), 15–27
- Kolko, J. (2007) 'The Tenuous Relationship between Design and Innovation'. *Artifact* 1 (3), 224–31

- Kotler, P. and Rath, G. A. (1984) 'Design: A Powerful but Neglected Strategic Tool'. *Journal of Business Strategy* 5 (2), 16–21
- Kuhn, T. S. (1970) *The Structure of Scientific Revolutions*. 2nd edn. Chicago: University of Chicago Press
- Levitt, T. (1986) *Marketing Imagination*. new, exp. edn. New York: Free Press
- Levitt, T. (1980) 'Marketing Success through Differentiation—of Anything'. *Harvard Business Review* January–February, 83–91
- Liedtka, J. (2013) 'Design Thinking: What It Is and Why It Works'. Working paper from the Design@Darden Design Thinking Forum [online]. available from <<http://batten.squarespace.com/storage/books-journals-articles/DSWP%2013-01%20rev%202-1.docx>> [7 July 2015]
- MacMillan, I. C. and McGrath, R. G. (1997) 'Discovering New Points of Differentiation'. *Harvard Business Review* July–August, 133–45
- Magretta, J. (2012) *Understanding Michael Porter: The Essential Guide to Competition and Strategy*. Boston: Harvard Business Review Press
- Mahdjoubi, D. (2003) 'Epistemology of Design'. in *Proceedings of the Seventh World Conference on Integrated Design and Process Technology* [online]. available from <<https://www.ischool.utexas.edu/~darius/Epistemology%20of%20Design-5-IDPT.pdf>> [4 September 2015]
- Martin, R. (2009) *The Design of Business: Why Design Thinking Is the Next Competitive Advantage*. Boston: Harvard Business Press
- Merriam-Webster (2014) *Merriam-Webster's Collegiate Dictionary*. 11th edn. Springfield, MA: Merriam-Webster
- Milman, N. B. (2010) *The Major Paradigms* [online]. available from <<http://www.nadaisland.com/doc/paradigms/>> [2 September 2016]
- Nonaka, Ikujiro. (1991) 'The Knowledge-Creating Company'. *Harvard Business Review* November–December, 96–104
- Norman, D. A. (2013) *Rethinking Design Thinking*. [19 March] available from <<http://www.core77.com/posts/24579/Rethinking-Design-Thinking>> [7 December 2016]
- Norman, D. A. (2010) *Design Thinking: A Useful Myth*. [25 June] available from <<http://www.core77.com/posts/16790/design-thinking-a-useful-myth-16790>> [7 December 2016]
- Norman, D. A. and Verganti, R. (2014) 'Incremental and Radical Innovation: Design Research vs. Technology and Meaning Change'. *Design Issues* 30 (1), 78–96
- Östman, L. E. (2005) 'Design Theory Is a Philosophical Discipline: Reframing the Epistemological Issues in Design Theory'. Sixth International Conference of the European Academy of Design. held 29–31 March 2005 at University of

- the Arts, Bremen, Germany. available from
<http://ead.verhaag.net/fullpapers/ead06_id178_2.pdf> [4 December 2016]
- Ozkul, T. (2008) 'Using Patents as a Tool for Reinforcing Constructivist Learning Environment in Engineering Education'. *International Journal of Education and Information Technologies* 2 (2), 157–66
- Paletz, S. B. F., Bogue, K., Miron-Spektor, E., and Spencer-Rodgers, J. (2015) Dialectical Thinking and Creativity from Many Perspectives: Contradiction and Tension. to be in *Psychological and Cultural Foundations of Dialectical Thinking*. ed. by Spencer-Rodgers, J. and Peng, K. Oxford: Oxford University Press. available from <<https://www.academia.edu/24691878/>> [7 December 2016]
- Patton, M. Q. (2002) *Qualitative Research and Evaluation Methods*. 3rd edn. Thousand Oaks, CA: Sage Publications
- Pedgley, O. F. (2007) 'Capturing and Analyzing Own Design Activity'. *Design Studies* 28 (5), 463–83
- Perkins, D. N. (1986) *Knowledge as Design*. Hillsdale, NJ: Lawrence Erlbaum
- Popper, K. R. (1940) 'What is Dialectic?' *Mind* 49 (196), 403–26
- Porter, M. E. (2008) 'The Five Competitive Forces that Shape Strategy'. *Harvard Business Review* January 78–93
- Porter, M. E. (1998) *Competitive Advantage: Creating and Sustaining Superior Performance*. with a new introduction. New York: Free Press
- Porter, M.E. (1996) 'What Is Strategy?': *Harvard Business Review* December 1996
- Ralph, P. and Wand, Y. (2009) 'A Proposal for a Formal Definition of the Design Concept'. in *Design Requirements Engineering: A Ten-Year Perspective*. ed. by Lyytinen, K., Loucopoulos, P., Mylopoulos, J., and Robinson, W. N. Berlin: Springer, 103–36
- Rehm, J. T. and Gadenne, V. (1990) *Intuitive Predictions and Professional Forecasts: Cognitive Processes and Social Consequences*. Oxford: Pergamon Press
- Rittel, H. W. J. and Webber, M. M. (1973) 'Dilemmas in a General Theory of Planning'. *Policy Sciences* 4, 155–69
- Rotman School of Management. (2005) *The Design of Business, Rather than Designing for Business, Leads to Greater Innovations Says IDEO President & CEO at Rotman Business Design(TM) Conference* [online]. available from <<http://www.prnewswire.com/news-releases>> [26 August 2016]
- Rubin, H. J. and Rubin, I. S. (2011) *Qualitative Interviewing: The Art of Hearing Data*. 3rd edn. Thousand Oaks, CA: Sage Publications
- Schön, D. A. (1992) 'The Theory of Enquiry: Dewey's Legacy to Education'. *Curriculum Enquiry* 22 (2), 119–39
- Schön, D. A. (1987) *Educating the Reflective Practitioner*. San Francisco: Jossey-Bass

- Schön, D. A. (1983) *The Reflective Practitioner: How Professionals Think in Action*. New York: Basic Books
- Sigalas, C. and Economou, V. P. (2013) 'Revisiting the Concept of Competitive Advantage: Problems and Fallacies Arising from its Conceptualization'. *Journal of Strategy and Management* 6 (1), 61–80
- Simon, H. A. (1996) *The Sciences of the Artificial*. 3rd edn. Cambridge, MA: Massachusetts Institute of Technology Press
- Simon, H. A. (1988) 'The Science of Design: Creating the Artificial'. *Design Issues* 4 (1/2), 67–82
- Singh, K. (2014) *Woodpecker Drill: Nature-Inspired Design* [online] available from <<https://www.behance.net/gallery/14640447/Woodpecker-Drill>> [12 December 2016]
- Stake, R. E. (1994) 'Case Studies'. in *Handbook of Qualitative Research*. ed. by Denzin, N. K. and Lincoln, Y. S. Thousand Oaks, CA: Sage Publications
- Stompff, G. (2012) *Facilitating Team Cognition: How Designers Mirror what NPD Teams Do*. Unpublished PhD thesis. Delft, Netherlands: Delft University of Technology
- Stubbs, M. (2001) *Words and Phrases: Corpus Studies of Lexical Semantics*. Oxford: Blackwell
- Tovey, M., Bull, K., and Osmond, J. (2010) 'Developing a Pedagogic Framework for Product and Automotive Design'. in *2010 Design Research Society (DRS) International Conference on Design & Complexity* [online] held 2010. available from https://www.researchgate.net/profile/Michael_Tovey2/publication/267971607_Developing_a_Pedagogic_Framework_for_Product_and_Automotive_Design/links/55ba2d6b08aec0e5f43e9369.pdf [14 December 2016]
- Van De Ven, A. H. and Johnson, P. E. (2006) 'Knowledge for Theory and Practice'. *The Academy of Management Review* 31 (4), 802–21
- Verganti, R. (2009) *Design-Driven Innovation*. Boston: Harvard Business School Publishing
- Vogel, C. M., Cagan, J., and Boatwright, P. (2005) *The Design of Things to Come: How Ordinary People Create Extraordinary Products*. Upper Saddle River, NJ: Wharton School Publishing
- Willem, R. A. (1990) 'Design and Science'. *Design Studies* 11 (1), 43–47
- Woods, T. (2015) *Peter Thiel's 7 Questions for Product Innovation* [online] available from <<http://blog.hypeinnovation.com/peter-thiels-7-questions-for-product-innovation>> [12 December 2016]
- Yin, R. K. (2014) *Case Study Research: Design and Methods*. 5th edn. Los Angeles: Sage Publications

APPENDIX

Three Case Histories of New Product Design and Development

1. Case History 1 Insta-Flo Dispenser Design and Development.....	4
1.1 Reflective Narrative History of the Case.....	5
1.1.1 Discussion of the First Generation Dispenser Invention from the Brooks 110' Patent: 7	
1.1.2 History Brooks Patent US 4,117,551 –Second Generation Dispenser	9
1.1.3 History Finn Patent US 4,516,694 1985 Flushing Dispenser Patent	10
1.1.4 History of Problem as Documented by Finn Patent US 4,516,694	10
1.1.5 History as Described and Cited by Brown US Patent 4,676,437	12
1.2 Benchmarking The Existing Solutions 1984 – 1985 Era Foam Kits	12
1.3 Description of the Design Challenge – Problem from Patent Records	13
1.3.1 Existing challenge directly taken from the Brooks 551' Patent:.....	13
1.3.2 Existing Challenge as Stated in the Finn 694' Patent:	14
1.3.3 Existing Challenge as Stated in the Brown 437' Patent:	17
1.3.4 The Knowledge Gap	17
1.4 Reflection on the Existing Dispenser Problems	17
1.5 Reflecting on the Design Needs of the Portable Kit Stakeholders	18
1.5.1 Framing and Re-Framing the Brooks 1974 Dispenser Problem:	19
1.6 Bringing Focus to the Design Process	23
1.6.1 Getting to the Root Cause of the Problem.....	24
1.6.2 The Brown Patent US 4,676,437 – 1987 (Applied for in 1985)	27
1.6.3 Exploring a new Solution to the Problem in the Spool Valve Design	29
1.6.4 Creation of the Spool Valve Design:.....	30
1.6.5 Sealing the Spool Valve.....	35
1.6.6 Creating and Testing the Prototypes	39
1.6.7 Platform Design and Dispenser Design Improvements.....	41
1.6.8 Updating the Dispenser	44
1.7 Reflection on Creating the Insta-Flo 2-Component Dispenser.....	49
1.8 Reflecting on the Differentiation by Design Process	50
1.9 Reflection on the Business Solution	51
1.10 Conclusion	52
2. Case History 2 – Anti- X- Over Nozzle Design and Development	53
2.1 Reflective Narrative History of the Anti- X- Over Nozzle Development.....	53
2.2 Benchmarking the Existing Solutions	58
2.2.1 History of Problem as Documented by Brown Patent US 6,021,961	58
2.3 Description of the Design Challenge - Problem from Patent Records	60
2.3.1 History of Problem as Documented by Brooks Patent US 4,117,551	60

APPENDIX

2.3.2	History of Problem as Documented by Brown Patent US 6,021,961	62
2.4	The Knowledge Gap	64
2.5	Reflection on the Problem as Documented by Brown Patent US 6,021,961	64
2.6	Reflection on the Needs	67
2.7	Bringing Focus to the Design Process	70
2.7.1	Getting to the Root Cause of the Problem	70
2.7.2	Designing the Backflow Prevention	71
2.7.3	Brown Patent 96' Anti-Cross Over Solution	72
2.7.4	The Design Needs of the Manufacturing Process	75
2.7.5	The Four Components of the Final Design	77
2.7.6	The Plastic Film Check Valve Design	78
2.7.7	The Nozzle Back Cap Design:	79
2.7.8	Front Mixing Tube Design	80
2.7.9	Mixing Element Design	82
2.7.10	Integration of the Components Design	83
2.8	Design Solution as Described by Brown Patent US 6,021,961	84
2.9	Reflection on the Differentiation by Design Process	86
2.10	Reflection on the Business Solution	87
2.11	Conclusion	91
3.	<i>Case History 3 – The Bionic Wrench Design and Development</i>	93
3.1	History of the Case	93
3.1.1	Seeking a Case history of the Differentiation by Design Process	93
3.1.2	Seeking the Right Problem to Solve	95
3.1.3	Luck Strikes the Prepared Mind	96
3.1.4	History as Described and Cited by Brown Patent 6,889,579	97
3.2	Research Benchmarking of the Existing Solutions	98
3.3	Description of the Problem from the Brown US 6,889,579 Patent Record	100
3.3.1	The Knowledge Gap	101
3.4	Reflection on the Problem	102
3.5	Reflection on the Needs	106
3.5.1	Performance Needs:	107
3.5.2	Need Finding Beyond Form and Functional Performance	108
3.5.3	Form Need Finding – Form Following Function	108
3.6	Bringing Focus to the Form and Functional Design Process	112
3.6.1	Getting to the Root Cause of the Problem	112
3.6.2	Benchmarking the Form and Functional Factors	114
3.6.3	Designing the body of the Bionic Wrench	115
3.6.4	Bionic Wrench Alternate Body Design Styles	123

APPENDIX

3.6.5	Bionic Wrench Alternate Handle Design Styles.....	123
3.6.6	Designing the Mechanism of the Bionic Wrench.....	124
3.6.7	Designing the Jaws.....	127
3.6.8	Designing the Component Tolerances	130
3.6.9	Choosing the Best Value in Hardness and Coatings	132
3.6.10	The 579' Brown Patent Outlines the Design Problems Addressed:	134
3.6.11	Choosing the Best Value in Material	134
3.6.12	Choosing the Best Manufacturing Process	135
3.6.13	Line Extension Design	139
3.6.14	Platform Design	140
3.6.15	Mass Customisation Design	142
3.6.16	Colour Scheme Design for Identity Among the Competitors.....	142
3.6.17	Trade Dress Design Strategy	143
3.6.18	Identity Design Logo-Mascot and Strategy.....	145
3.6.19	Company Name, Imagery and Logo Design	146
3.6.20	Product Names Design.....	147
3.6.21	Packaging Design.....	148
3.6.22	Choosing the Best Component, and Manufacturing Partners	150
3.6.23	Intellectual Property Design Strategy	151
3.7	Reflection on the Designed Solution	159
3.8	Reflection on the Commercial Business Solution.....	160
3.9	Reflection on Differentiation by Design as a Design Strategy.....	161
3.10	Concluding Reflection.....	162

Case History 1 – Insta-Flo Dispenser

1. Case History 1 Insta-Flo Dispenser Design and Development

This case explores the design evolution of a family of plastic foam dispensers that evolved into a mature product technology over the last 45 years. Early versions of the patented dispensers were created and patented by inventor Bill Brooks. These early dispensers were based on traditional engineering applications of valve-metering methods to solve the metering dispensing problem. Although significant effort was expended to overcome the processing problems associated with the polyurethane chemical components, early attempts to create a reliable product technology with these methods were unacceptable but developed into a marginally acceptable product. The ultimate solution, which is the subject of this case history, is still the marketplace benchmark 30 years after its invention was an elusive but illustrative narrative of how the design process evolves from the traditional engineering process into new and novel new product when existing disciplinary knowledge falls short.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 1.1: Insta-Foam 1985 Graphic Emphasizing “The Foam Machines in a Carton”

Case History 1 – Insta-Flo Dispenser

1.1 Reflective Narrative History of the Case

This case deals with the processing of polyurethane components. Polyurethane (PU) is a thermosetting plastic created by the reaction of a number of constituents blended into two main components. Polyurethane chemistry has a tremendous amount of versatility, resulting in finished plastics ranging from lightweight foams (pillow foam and foam insulation) to dense elastomers (roller-skate and skateboard wheels). The particular focus of this product application was the creation of a portable two-component polyurethane-creating kit that could be utilised at a remote job site without the need for additional utilities or equipment to create the polyurethane foam. The product goal was a “Foam Machine in a Carton” (see Figure 4-1) this case illustrates that the ultimate solution, having competed as the dominant technology in the marketplace, resulted from a very different approach to the problem than earlier attempts. This approach can be described as a designerly process of enquiry into novel methods of solving the problem as opposed to previous attempts to solve the problem utilising traditional engineering solutions.

The foundational patents for this technology originated with inventor Bill Brooks, who founded Insta-Foam Products. While Brooks recognised the tremendous potential of this unique chemistry, his primary challenge was how to process, dispense, meter the ratio, and mix the components outside the controlled conditions of a dedicated manufacturing plant. With the reactivity of the Isocyanate (A) component chemistry, this journey proved an elusive design evolution of technologies, which is the subject of this case. The potential for this portable-kit technology application of Polyurethane (PU) chemistry was limitless, as Brooks had envisioned, and we know today almost 50 years after the first attempts at this technology. The journey was a more of an odyssey of creativity than the lightning strike of inspiration that popular mythology depicts. The first case of this series (Insta-Foam’s early years’ case.) describes the processing problems.

Early in my career, I aspired to the goal of obtaining a patent, I do not know where it this aspiration originally came from or why. However, my passion was real, the existing Brooks dispenser work, after repeated failures, I decided that I to find a better way. I can reflect on that moment as an important event that charted a creative

Case History 1 – Insta-Flo Dispenser

pathway to achieving my design and invention goals which has defined the basis of my life's profession.

My superior at the time was a man named Roger Fisher; president of Insta-Foam Products, where I had been hired as project manager. I explained to Roger that no matter how hard I tried I could not find a way to make the old design work for the new application. Roger was supportive but clear. Through the years, my predecessors had spent considerable time and effort trying to create a new design, and although the need was there, he could not throw any more money at it. I had to find a way to make the existing design work; a competitor had entered the portable kit business with an improved dispenser. This was a frustrating position to be in, as I was eager to prove myself in this new position but finding myself assigned a seemingly impossible task of making the existing design work

Completely immersed in this assignment, I literally dreamt about it at night. As I continued to attempt a workaround of the existing dispenser's limitations, an inspiration came to me. Based on the performance needs I had identified, I had a vision of a better way to create a new dispenser, but a direct mandate to find a way to make the existing design fly. I did not want to be insubordinate, so I continued to struggle with the current design at work, while I also engineered my redesign in the evenings and on weekends.

Fortunately, we had a machine shop that did a lot of work with the company, and I was able to persuade the shop's owner, Jess Lucancik, to put in a little pro-bono work with me on weekends to create prototypes. Jess knew the existing designs' shortcomings well, and he was supportive of my new design. We were a good customer, and as a supplier, he had a strategic interest in our continued business health. Beyond that, Jess was one of the most intelligent and supportive people I have ever met, and I will forever be grateful for his support of my work on this and many subsequent projects. After about three weeknights and weekends, I had a working prototype that I was able to test in the lab to validate its performance. It was, as I had envisioned, a game-changing invention in that industry.

The prototype although rough, worked like a charm. With the confidence of the success, I confided in Roger what I had done and organized a demonstration in the lab. Knowing the issues well, upon seeing the performance, and the obvious

Case History 1 – Insta-Flo Dispenser

advantages, Roger immediately sanctioned an expansion of my project to include the redesign. With some funding and additional resources, I had the project designed, tested and ready for tooling in less than three months. This discovery rewarded me with my first ever patent, and Roger received that elusive new dispenser for the company's core product line he had invested in dearly. Although I had other inventive designs in my previous work, none were pursued as patents for various reasons; I look fondly to this experience as my career launch as a Design-inspired Inventor.

I have romanticized this design experience in 1985 as it has given direction to my life's passion, launched by a simple vision, inspiring 35 more years of creative differentiation. Today with over 40 U.S. Utility patents, these similarly repeated experiences have conspired to place me here at my computer, searching reflectively to find a narrative voice for these cases. A story about my journey of seeking to add value through inventive design that creates competitive product advantage. I have captured this process in a slogan that is the formation of my life, work, business, and now teaching, as the strategy I call “Differentiation by Design.”

1.1.1 Discussion of the First Generation Dispenser Invention from the Brooks 110' Patent:

This case data relies upon the historical patent records to support the reflections of the researcher. Patents are a rich source of information regarding not only the invention but also the existing problem that the invention has solved. Thus for support data on the problem and solution I will rely on the historical patent language to inform and provide evidentiary support for the reflections in this case.

Excerpted from the Brooks 110' Patent:

The types of products with which the instant invention is concerned are primarily the closed cell foam types of product used for insulation purposes in building structures and open the celled product used for packaging applications.

The components of the foam are passed at high pressures above 40-50 p.s.i. [pounds per square inch] through a gun which serves to meter and mix the components thoroughly in a nozzle from which they are discharged. According to the invention, chemicals components are taken directly to a job site in pre-pressurised cylinders, or shipped in bulk tanks requiring external pumps or other sound of pressurization. Here, the amount of product required to be

Case History 1 – Insta-Flo Dispenser

dispensed is not so large as to require permanent, expensive equipment, as would be used in a factory.

However, the amount of product used is significantly larger than could be accommodated by using small, individual aerosol cans, for example. The individual containers of the components carry from several pounds up to perhaps 25 to 50 or even more pounds or more of each component. These tanks are sufficiently portable to be moved about on the job site by one worker, but yet are able to provide sufficient foam to provide several hundred or thousand board feet of coverage. With the ability of the chemical supply tanks to be moved about, there has been a significant demand for a dispensing gun which would provide the advantages and characteristics of low-cost, operating flexibility and reliability in use (Brown 1987: col. 1–2; bullet points inserted for clarity).

This item has been removed due to 3rd Party Copyright.
The unabridged version of the thesis can be found in the
Lanchester Library, Coventry University

Figure 1-2: Image from the Brooks 110' Patent for the First Generation Dispenser

Case History 1 – Insta-Flo Dispenser

1.1.2 History Brooks Patent US 4,117,551 Second Generation Dispenser

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 1-3: Brooks Attempt to Solve the Problem with a Flushing Dispenser Design

Case History 1 – Insta-Flo Dispenser

1.1.3 [History Finn Patent US 4,516,694 1985 Flushing Dispenser Patent](#)

1.1.4 [History of Problem as Documented by Finn Patent US 4,516,694](#)

While Insta-Foam continuously attempted to improve the existing dispensing system, the industry simply struggled with the dispenser failure rate for another 10 years until a customer of Insta-Foam's named Versa-Foam sought to redesign the portable kit dispenser. Finn the inventor of the Versa-Foam dispenser greatly improved the design as well as the quality of the materials used in his dispenser design. To address the crossover problem, Finn introduced a flushing port into his dispenser that could be used at the end of a job to purge the A chemical from the passageways. It also could be used quickly after a crossover to recover the dispenser.

Below is the Finn 694' Patent describing his improved dispenser attempt to overcome these problems in the late mid 1980's era dispensers. The patents thoroughly describe the problems that the users were facing in the marketplace.

Case History 1 – Insta-Flo Dispenser

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 1-4:: Finn 694' Patent Displaying Dispenser, Nozzle and Flushing Apparatus

Case History 1 – Insta-Flo Dispenser

1.1.5 History as Described and Cited by Brown US Patent 4,676,437

Patents have an obligation to state the background of the application, thus I will let the Brown 437' patent disclose the problem faced in 1984-1985-time frame for portable foam kits by the following excerpt from the Brown 437' patent:

The present invention relates generally to mixing and dispensing guns for use in the plastic foam industry, and more particularly, to a design of gun which is adapted for easy, low-cost mass production manufacture and which is capable of performing the functions needed for precise mixing and dispensing of thermosetting chemical products resulting from the mixture of two reactive chemical components.

In recent years, there has been an ever increasing use of polyurethane and like plastic foams for a number of applications. Urethane and related products, including isocyanurates silicones, phenolics and epoxies, are well known as having a number of desirable characteristics. These include the potential for excellent heat insulation, compatibility with low-cost blowing agents, reproducibility of chemical characteristics, and excellent chemical and physical properties in the finished product.

Moreover, urethane foams, being the reaction product of two individual components, may be varied in chemical composition for a number of purposes. Thus, urethane foams may be formulated so as to provide a finished product which is quite rigid, semi-rigid, or somewhat flexible and/or elastomeric. Foams of the kind in question may be made with almost exclusively closed cells, or with a desired proportion of open cells (Brown 1987: col. 1).

1.2 Benchmarking the Existing Solutions 1984 – 1985 Era Foam Kits

By 1984, there were 3 main dispensers on the market, the Brooks US 3,784,110, the Brooks 4,117,551 (manual flushing version) and the Finn US 4,516,694 (manual flushing version) (see Figure 1-2). The Finn 694' dispenser had introduced a way to flush the pathways of the A component after the dispenser use in a portable way with solvent. This development introduced a convenient way to clean and maintain the dispenser, while Brooks had introduced a flushing system in his 551' patent, it did not work for the portable usage of the kits. The Insta-Foam domination of the portable kit business was being severely threatened by the Finn design. It was at this time that I joined Insta-Foam as a project manager.

Case History 1 – Insta-Flo Dispenser

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 1-5: Images from Brooks 110', Brooks 551" and Finn 694 Patents

The Brooks dispenser preceded the Finn dispenser by 10 years, and it was the pioneering design that created the portable kit marketplace. Versa-Foam a distributor for Insta-Foam sought to enter the marketplace with their own dispenser, designed by Finn, resulting in the 110' patent. While Insta-Foam had attempted to improve the original Brooks design, it had proven elusive. The development of the Finn dispenser had attacked the Insta-Foam stronghold on the market for the first time; Finn had patented a manual way to use solvent flush to clean the dispenser after use. This flush although troublesome, and not the most environmentally desirable solution did address the A port clogging issue with the Brooks 110' design as discussed in the in the above patents. Thus, I arrived at Insta-Foam when there was a significant threat to their dominance of the market for portable foam kits.

1.3 Description of the Design Challenge – Problem from Patent Records

1.3.1 Existing Challenge Directly Taken from the Brooks 551' Patent:

Experience has shown that the components of urethane foam can be selected so as to provide a relatively quick-hardening product fluid. After the material is sprayed on or into the target area, foam product solidification begins. Now, this solidification occurs not only in the desired target area, but in residue product which may remain within the dispensing gun after spraying has been stopped. Residue foam product which has hardened inside parts of the gun make gun cleansing and subsequent use difficult.

Recently, the use of urethane foam as an insulation and packing material has found increased favour in applications providing target areas of restricted size and shape. When workers are dealing with such restricted target areas, they often find it necessary to spray or apply the foam in an intermittent manner.

Case History 1 – Insta-Flo Dispenser

While relatively short time lapses between sprayings can, under some circumstances, be tolerated without foam set-up and gun clogging, time lapses of greater duration permit the fluid constituents to either completely or partially solidify within the gun components, thereby completely or partially clogging the gun. Poor gun performance and an insulation or packing job of degraded quality result. Worker annoyance and hurried efforts can also occur, and can indirectly contribute to a finished product of less than maximum quality.

This problem of partial gun clogging during intermittent spraying operations can be minimized or eliminated by purging those parts of the gun wherein the fluid components are co-mingled, mixed and discharged with a non-reactive purge fluid (Brooks and Heinzl 1978)

1.3.2 Existing Challenge as Stated in the Finn 694' Patent:

The A resin or polymeric isocyanate, on the other hand, will solidify upon exposure to air and in time will present a clogging problem or otherwise cause malfunction of relatively movable parts such as valve components with which the A resin comes in contact. The solvent supplied with each kit, therefore, is principally intended to dissolve the unmixed A resin and effectively remove it from any portion of the gun with which it comes in contact after passing the gun valve which isolates from the atmosphere the A resin remaining in passageways extending from the tank up to the valve. However, it is difficult in practise to assure circulation of the solvent into gun parts and other internal surfaces located downstream from the A resin valve. The result of this difficulty, in turn, is often the clogging of the A resin passageway to a point where the gun is no longer useful for dispensing all of the resin supplied with each kit.

The replaceable nozzle foam dispensing guns heretofore developed have been highly effective with pre-packaged resin kits capable of supplying up to 50 cu. ft. or more of the dispensed foam product. Moreover, the dispensing guns presently in use are highly effective in terms of meeting the economic constraints of temporary use, that is, disposal after resin supplied with each package or kit is dispensed. There is a need however for alleviating the problem of clogged ports and gun valving as a result of the A resin hardening upon exposure to the atmosphere.

In accordance with the present invention, a foam dispensing gun of the type referred to is provided with a re-closable flushing port by which the fluid passageway extending from the low pressure or downstream side of a closure valve at least for one of the resin supply passageways, may be thoroughly flushed with solvent after use and thereby avoid the deleterious effects of resin solidifying in the passageway upon exposure to the atmosphere. The flushing port extends to the gun body exterior in a manner such that the solvent may be injected easily and under pressure developed by manual compression of a

Case History 1 – Insta-Flo Dispenser

squeeze bottle, for example, in which the solvent is initially supplied and contained for use. Where only one flushing port is provided, it extends to the internal gun passageway through which the air reactive resin (e.g., polymeric isocyanate) is fed during normal operation of the gun (Finn 1985: col. 1–2; emphasis added).

Excerpted from Finn 694”Patent:

In accordance with the present invention, a foam dispensing gun of the type referred to is provided with a reclosable flushing port by which the fluid passageway extending from the low pressure or downstream side of a closure valve at least for one of the resin supply passageways,

The foam dispensing gun may be thoroughly flushed with solvent after use and thereby avoid the deleterious effects of resin solidifying in the passageway upon exposure to the atmosphere.

The flushing port extends to the gun body exterior in a manner such that the solvent may be injected easily and under pressure developed by manual compression of a squeeze bottle, for example, in which the solvent is initially supplied and contained for use.

Where only one flushing port is provided, it extends to the internal gun passageway through which the air reactive resin (e.g., polymeric isocyanate) is fed during normal operation of the gun.

The principal object of the present invention, therefore, is the provision of an effective solvent flushing system for foam dispensing guns of the type aforementioned (Finn 1985: col. 2; bullet points inserted for emphasis).

A flushing arrangement for a foam dispensing gun operation to dispense at least one resin component which solidifies on exposure to air and including a gun body with an internal passageway adapted to be closed by a valve to establish a passageway portion located downstream from the valve in the context of resin flow past the valve when opened. The flushing arrangement includes a port extending from the exterior of the gun body to the passageway portion immediately downstream from the closed valve so as to enable the circulation of solvent from a pressurised source, such as a squeeze bottle, throughout all surfaces with which the resin comes in contact in the passageway portion (Finn 1985: abstract).

The design of the overall system is such that the separately supplied resins are kept from contact with each other until they are mixed in and discharged from the gun nozzle.

Case History 1 – Insta-Flo Dispenser

The mixture of resins quickly sets up as a rigid foam product which is substantially insoluble and thus extremely difficult, if not impossible, to remove from surfaces with which it comes in contact.

Also, because of these characteristics, any substantial interruption in operation of the gun is likely to cause the mixed resins to set up in the nozzle itself and thus prevent further foam dispensing operation.

It is for this reason that the nozzles of the gun are replaceable and that each pre-packaged kit or system is provided with an adequate supply of the replaceable nozzles.

When the dispensing gun, connected by hoses to the pressurised containers of the two resins, is to be left unattended for an extended period of time such as a lunch break or overnight, recommended procedure involves removing the used nozzle and cleansing the gun of any residual resin using the solvent supplied with the pre-packaged kit. In this respect, the B resin or polyol amine is relatively inert and will remain as a liquid even when exposed to air for a substantial period of time.

The A resin or polymeric isocyanate, on the other hand, will solidify upon exposure to air and in time will present a clogging problem or otherwise cause malfunction of relatively movable parts such as valve components with which the A resin comes in contact.

The solvent supplied with each kit, therefore, is principally intended to dissolve the unmixed A resin and effectively remove it from any portion of the gun with which it comes in contact after passing the gun valve which isolates from the atmosphere the A resin remaining in passageways extending from the tank up to the valve. However, it is difficult in practice to assure circulation of the solvent into gun parts and other internal surfaces located downstream from the A resin valve. The result of this difficulty, in turn, is often clogging of the A resin passageway to a point where the gun is no longer useful for dispensing all of the resin supplied with each kit.

The replaceable nozzle foam dispensing guns heretofore developed have been highly effective with prepackaged resin kits capable of supplying up to 50 cu. ft. or more of the dispensed foam product. Moreover, the dispensing guns presently in use are highly effective in terms of meeting the economic constraints of temporary use, that is, disposal after resin supplied with each package or kit is dispensed. There is a need however for alleviating the problem of clogged ports and gun valving as a result of the A resin hardening upon exposure to the atmosphere (Finn 1985: col. 1–2; bullet points inserted for clarity).

Case History 1 – Insta-Flo Dispenser

1.3.3 Existing Challenge as Stated in the Brown 437' Patent:

Another desirable characteristic would be a gun having porting designed so as not to have any dead space for the accumulation of the chemicals in the port where they may be exposed to the atmosphere. Specifically, where the isocyanate component of the polyurethane would be allowed to have contact with atmospheric moisture (humidity), react and crystalize in the port, rendering the gun inoperable.

A further objective of the invention is to provide a gun which includes a valve assembly adapted to ensure that the components are not mixed with each other prior to their discharge into the mixing chamber of the associated nozzle.

A still further object is to provide a gun wherein the valve provides positive product flow shutoff, and wherein the outlet passage or passage downstream of the flow control valve is extremely short and has close contact with the nipple ports of an associated nozzle (Brown 1987).

1.3.4 The Knowledge Gap

How can a metering-mixing-dispenser for PU foam be designed to eliminate the passageway blockages created by the isocyanate fouling the dispenser?

1.4 Reflection on Existing Dispenser Problems

Firstly, in 1978, Brooks sought to overcome the “A” chemical hardening in the passageway by using a pressurised source of third stream cleaning fluid. While this could the passageways, the system created relied on a much more complicated valving and porting arrangement to achieve the flushing. In addition, the storage and supply of the flushing fluid added cost and complexity. The dispenser’s reliance on the pressurised water system in practise virtually eliminated the portability opportunity to be used in the kits. The design reflects the desire to overcome the problem with a traditional engineering type solution; unfortunately, it was treating the symptom of the problem and not the root cause of the problem. Thus, it worked to a limited extent in non-portable applications like creating packaging foams as noted in the patent, and some in-plant uses of the rigid insulation foams. However, the design did not solve the problem for the portable foam kits, the heart of the company’s product line and profits.

Case History 1 – Insta-Flo Dispenser

Secondly, Finn seeking to solve the “A” component-hardening problem with his design eliminated some of the passageways when compared to the Brooks design but unsuccessfully eliminated the “A” clogging of the internal passageways that remained. Seeking to address this, Finn chose to add an access port to the dispenser that can be manually opened by the user and allows for the use of a squeeze bottle of solvent to purge the A component passageway after use. This solution had its advantages over the existing Insta-Foam dispenser for the portable kits patented in by Brooks1974 and were still being used by Insta-Foam in the mid 1980’s. The improved Finn dispenser had put the Insta-Foam business dominance at severe risk.

1.5 Reflecting on the Design Needs of the Portable Kit Stakeholders

Insta-Foam was at risk for losing its dominance in the portable kit business to Versa-Foam and they needed a solution. At this point in my career I was very engineering practise-orientated in my design work, my problem-solving was technically-focused and my solutions would follow a normal optimisation of existing knowledge solutions type process in my practise. Although I did have a lot of experience working with this challenging isocyanate (A component) chemistry on other non-portable meter mixing processing equipment. The stakeholder-operators of this equipment enjoyed the ability to maintain and sustain the ability to easily flush and clean the A passageway continuously during production (see Figure 1-6). When confronted with the challenge of solving the dispenser failure problem, I immediately understood that those traditional in-plant and not portable solutions would not work for this problem with portable kits.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 1-6: Web image of a Plant PU Processing Machine Compared to a Portable Kit

Case History 1 – Insta-Flo Dispenser

My boss Roger Fisher had tasked me with finding a solution to the dispenser failures in the marketplace, challenging me to find a way to make the existing design work. I worked diligently to find a solution that would utilise the existing dispenser design but I could not find a solution. As a practitioner, I was stuck with a situation where the existing technology knowledge of practise would not work in this instance to solve the problem. I needed to seek another way to eliminate the A chemical reacting and hardening in the passageways of the dispensers.

Also from my analysis, I understood that I needed to deal with the other problems identified with the Insta-Foam dispenser; these shortcomings had become more visible, as the Finn dispenser had significantly raised the performance standard and stakeholder benchmark in the marketplace. Seriously threatening the marketplace dominance created by Insta-Foams pioneering of the Brooks technology over the past 10 years. Simply stated the stakeholders needed a low-cost, reliable mixing and dispensing gun for portable kits, which did not foul upon usage.

1.5.1 Framing and Reframing the Brooks 1974 Dispenser Problem:

The Brooks 110' 1974 dispenser was the pioneer, now 11 years since its patent issued and close to 14 years in the marketplace it was under competitive pressure from the newly introduced Finn 694' dispenser, (see Figure 1-4). The table below benchmarks each of these dispensers based on performance at that 1984-85-time period.

Case History 1 – Insta-Flo Dispenser

Benchmarking Dispensers	
Brooks 110' Dispenser	Finn 694' Dispenser
A passageway would easily clog	Developed a means of flushing passageways
Off ratio foam – blockage of A passage	Flushing could reduce problems
Lead lag – sticking of the A valve	A side needle valve would still stick
A – B flowing rearward crossing over	This situation was similar
Unable to meter output	Needle valves metered better
Dispensing with a clogged nozzle	This situation was similar
Dispenser would be source of leaks	Leaks at valving rods on A & B sides

As can be seen above, the Finn 694' dispenser had improved the performance expectations of the marketplace and literally changed the existing performance expectation paradigm of the stakeholders. When there were no options other than the Brooks 110' dispenser for the kit business, users had no other choices thus lower levels of expectations, and acceptance of the problems. The Finn 694' raised the bar in the following ways:

- Gave users the ability to easily flush the dispenser passageways
- Gave users the ability to meter the foam output on ratio
- Reduced the lead – lag issue seen with A sticking of the valves
- The Finn 694' design did not eliminate
- Sticking of the needle valves, particularly the A valve
- Crossover when the dispenser was activated with a clogged nozzle
- Leak paths created at valving rods for needle valves
- Bringing Focus to the Design Process

Problem and need finding research in both the functional and user spaces is necessary to understand the problem and the needs. As an experienced practitioner with 35 years of practise, I can now see that although this was a challenging project, I did have some good functional problem-solving focus to draw from. In addition, my experience in the technology as well as the marketplace served me well in bringing focus to both the functional engineering issues as well as the user issues.

Case History 1 – Insta-Flo Dispenser

Upon reflectively benchmarking the performance characteristics of each dispenser, running side-by-side trials, and working with users in the field to understand their needs, I set about seeking opportunities to understand and develop a strategy for redesigning the dispenser. I was working on a way to get the existing Brooks 110' dispenser to work better, but I had also challenged myself to work on a redesign as a parallel process solution. The image (see Figures 1-5, and 1-6) are a schematic drawing of the function of the Brooks 110' design that I was charged with improving, but I also worked separately on creating a new design. It

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Case History 1 – Insta-Flo Dispenser

Functional Problem Analysis

Observed Problem	Probable Cause
Off Ratio Foam	One component flow restricted, Blind passageways cannot be cleaned, A & B pushrods are independent, Trigger does not act equally on each push rod, Handle is weak and "wobbly," Check valves do not meter
Lead Lag	One component flow restricted, Blind passageways cannot be cleaned, A & B pushrods are independent, Trigger does not act equally on each push rod, Handle is weak and "wobbly," Check valves do not meter
A – B Crossover	Material flowing rearward from nozzle, Activating with a blocked nozzle, Activating with unequal flow and pressures
Unable To Meter Output	Ball Valves do not meter, A & B Pushrods are independent, Trigger does not act equally on each push rod, Handle is weak and "wobbly"
Dispensing With A Clogged Nozzle	Cannot see if nozzle is clogged
Dispenser Would Be Source of Leaks	A component destroying seals, Valving push rods difficult to seal

Portable Kit User's Needs Analysis

Observed Needs	Probable Requirements
Users needed quality foam without hassle	A – B metering without a passageway clogging
Users wanted to be able to start and stop	Dispenser ability to recover from activating with a partially or fully clogged nozzle
Users did not want to flush the dispenser	Design a dispenser that did not require flushing

Case History 1 – Insta-Flo Dispenser

1.6 Bringing Focus to the Design Process

On reflection Brooks as well as the technical staff that followed Brooks previously understood these potential root causes. The diagram below clearly shows the blind passageways of the material flow path that become exposed to the moisture in the air, or backflow of material from the nozzle and can become obstructed. For the resin component passages, moisture reaction was not an issue, but for the isocyanate or A component this was a critical problem as the isocyanate readily reacts with moisture in the air. (see Figure 1-8).

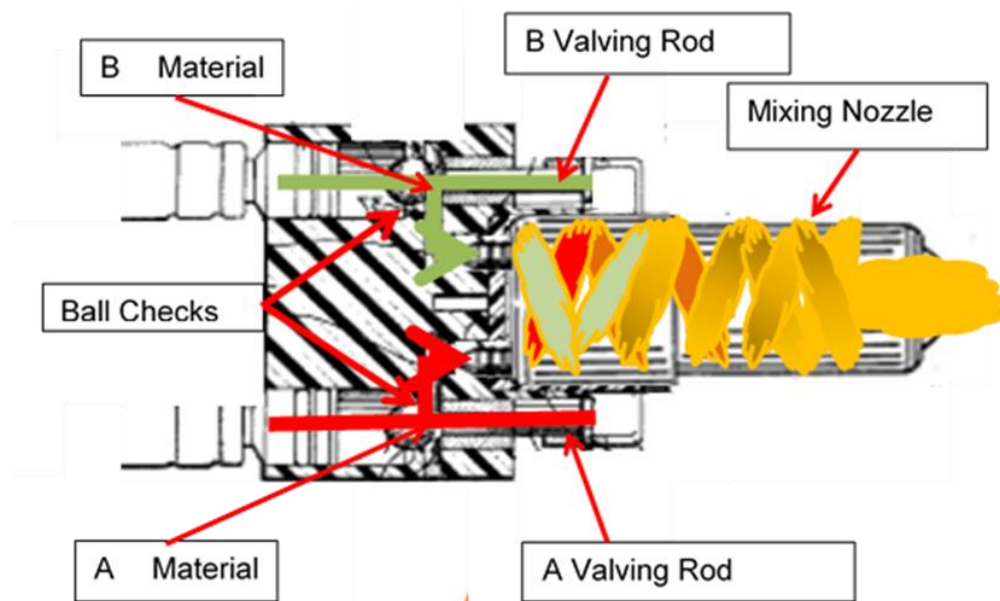


Figure 1-8 Diagram of the Blind Flow Passageways of the Existing Brooks Dispenser

While there were continuous improvements over the years by Insta-Foam to address the problems, they were always addressing the symptoms of the problems. In my analysis, the lack of focus on eliminating the root causes of the problems, directed the improvement efforts at the wrong target. This lack of focus on the root of the problem is very easy to fall victim to, especially when under pressure to get a quick fix. I was under a similar pressure at the time when I was directed by my boss to fix the existing dispenser in a way to solve the problem, but because of my experience with this chemistry and problem, I realised that there was a reason why those before me could not correct the problem. The key to my designed solution was the fact that I was able to eliminate the root sources.

Case History 1 – Insta-Flo Dispenser

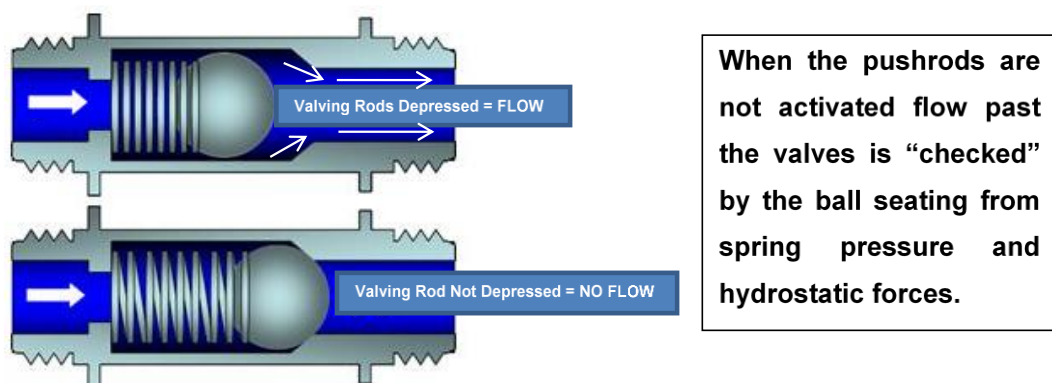
1.6.1 Getting to the Root Cause of the Problem

Root Cause Design Opportunities

Problem Causes:		Design Challenge
• “A” Component reactivity	->	Constraint
✓ Blind Passageways	->	Eliminate Passageways
✓ A & B Valves Independent	->	Connect the Valves
✓ Pushrods source of sticking	->	Eliminate Push Rods
✓ Nozzle Backflow	->	Eliminate Backflow
✓ Ball Valves Do Not Meter	->	Use Metering Valves
✓ Cannot See If Nozzle Is Used	->	Use Clear Plastic
✓ Handle/Trigger is Weak	->	Strengthen Trigger/Body

Figure 1-9 Root Cause Analysis of Problems and Design Challenges for the Re-design

I first tackled the valving design, as the sources of many of the problems centred on this area, and the Finn 694' dispenser had raised the bar in the marketplace by introducing the ability for the user to selectively meter or vary the output of the dispenser while maintaining the ratio. Finn used traditional needle valves to accomplish this and designed extended tips beyond the needle to act as pushrods similar to the Brooks 110' method of opening the valves with a trigger depressing push rods. While Finn did improve the metering with needle valves, he did not address the unequal opening issues with this method nor the leakage problem of the pushrods seals being destroyed by the A component during repeated activations.



Case History 1 – Insta-Flo Dispenser

The principle of using ball valves to control the flow in Brooks and Finn Dispenser designs was widely used in hydraulic and pneumatic systems. However, relying on the pushrods to always work and respond in unison was problematic in a dispenser application because of the sticking problem created by the A component in use. I quickly realised that I needed a different approach to activate the metering valves!

Moving beyond the need for an improved valving method, I then brought focus to the passageways that created a space for blocking flow forward of the valve. My analysis of the problem identified that this blockage occurred because of two primary causes.

1. The obvious situation is where A chemical would harden in those passageways beyond the valve when left exposed to any atmosphere with moisture or humidity in it. This was virtually all of the portable kit outdoor usages.
2. The second, and not so obvious, was the passageways beyond the valve being clogged with crossed-over reacted foam flowing backward from the nozzle back into one or both the A and B passageways.

Two conditions by the operators created this condition:

- a. Upon activating the dispenser with a clogged nozzle, and the reacting material expanding with nowhere to go forward. The ensuing pressure build-up in the nozzle chamber would drive the reacting foam rearward into the passageways and even at times past the valves, both Brooks 110' as well as Finn 694' designs partially or completely clogging and fouling the dispenser.
- b. During the kit activation, if the operator only opened one pressure container and not the other, the force of the pressurised side would drive the pressurised component into the mixing nozzle and rearward into the unpressurised passageway contaminating it. When the operator realised this and opened the other component pressure cylinder the chemicals would react in the passageway that was contaminated causing blockage.

Case History 1 – Insta-Flo Dispenser

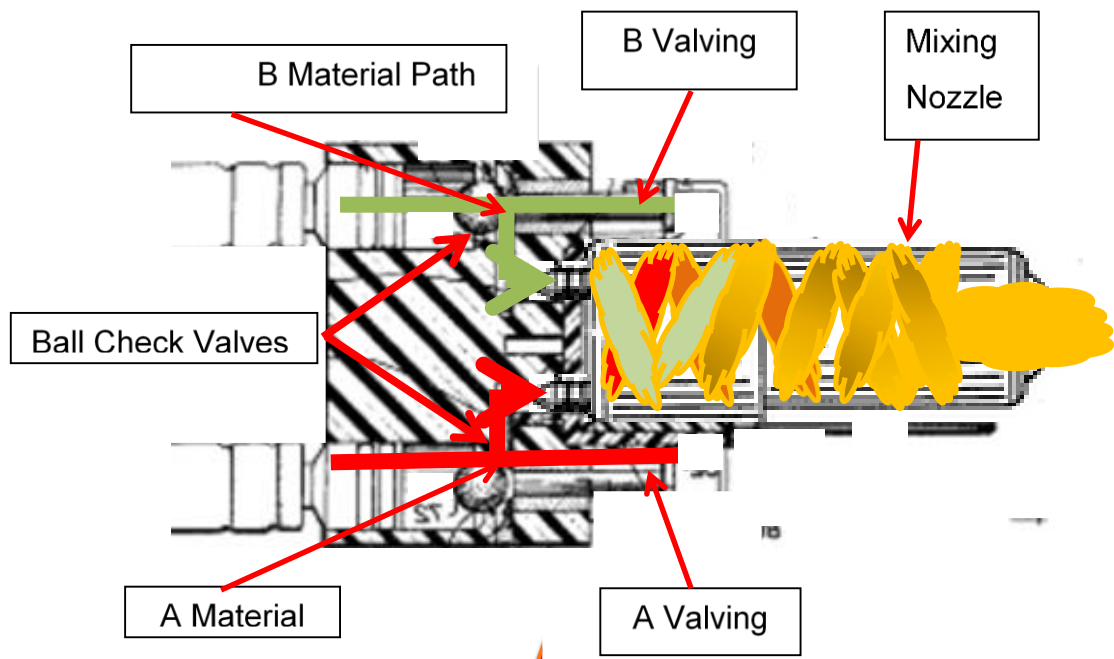


Figure 1-11 Diagram of Material Flow Path through Brooks 110' Dispenser and Mixing Nozzle

Unfortunately, as often happens in new design, there were unintended consequences of this pushrod-based design above (see Figure 1-11). While ball check valves worked well in many traditional engineering areas, they were problematic for metering of components on a consistent flow ratio of one to the other, as in this application. Even the improved Finn 694' version that utilised the needle valves succumbed to the same problems of the Brooks design when using the pushrods as an activation method. The A reactivity with atmospheric moisture and ensuing blockage of the dispenser A passageway was the Achilles heel of these dispensing systems; any design must address this constraint.

Functionally the pushrods created a site where the portion of the rod exposed to A chemical during activation would pass through the seal and be exposed to the moisture in the air, this caused reaction and crystallisation on the push rod that destroyed the seal once reactivated, creating A component leakage exacerbating the problem. When traditional practise built on the existing paradigm knowledge falls short and the practitioner still must solve the problem, it is time to put the design hat on and seek a new and novel problem-solving method. It has been my experience that these novel solutions arise by directing your design efforts at addressing the root causes of

Case History 1 – Insta-Flo Dispenser

the problem, in a designerly form of enquiry built on much more research than traditional practise-based problem-solving requires.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

**Figure 1-12 Brooks and Finn Existing Designs Relying on Pushrod Activators of the Valves
(Brooks 1974 and Finn 1985)**

Thus, it was obvious that my functional design requirements for a new dispenser depended on designing a new valving method or system to overcome the failure mode created by the pushrods:

My functional analysis of the failure modes provided the following insights:

1. Eliminating pushrods
2. Eliminating dead space passageways exposed to air-moisture
3. The ability to meter the components on ratio
4. Connecting the valves in some way to eliminate lead - lag
5. Minimizing or eliminating components

1.6.2 The Brown Patent US 4,676,437 – 1987 (Applied for in 1985)

The Brown 437' Patent reflects a complete new direction in meter mixing and valving technology for the portable kit business, this design changed the paradigm of the business, and although introduced in 1985, it remains the dominant product functional and form design in the marketplace over 30 years later. There have been two design updates and some additional improvements over the year, but the valving design that eliminated the heart of the root cause problem-remains at the core of the dispenser's technology. While this spool valve design virtually eliminated the dispenser failures, a second nozzle redesign discussed in Case History 2 did eliminate the dispenser problems in the marketplace.

Case History 1 – Insta-Flo Dispenser

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 1-13 Brown US Patent 4,676,437 (Brown 1987)

Case History 1 – Insta-Flo Dispenser

1.6.3 Exploring a New Solution to the Problem in the Spool Valve Design

Seeking to find a solution to the requirements I identified in my analysis, I continued to brainstorm various valving methods in my mind. This mental modelling is a common occurrence in thinking and is referred to as dialectic reasoning. Practitioners must seek new knowledge solutions when the existing knowledge of their practise is insufficient to solve the problem. The designer, with knowledge of what is in existence, cognitively poses possible new solutions mentally to simulate potential improvements iteratively. This ping-pong match of ideas and reflection on the value and potential of the ideas to meet the requirements is an essential part of the creative design process. Reflecting on my thought process at that time, although very aware of the common valving methods in practise, I could not identify one that would work in light of the A chemical reactivity with moisture constraint. Although in my past experience had proven to me that ball valves did work fairly well in the larger industrial equipment process for processing polyurethanes. Ball valves have seat-seals that completely captured them and although they rotated, they never allowed the wetted surfaces to become exposed to the atmosphere (see Figure 1-14).

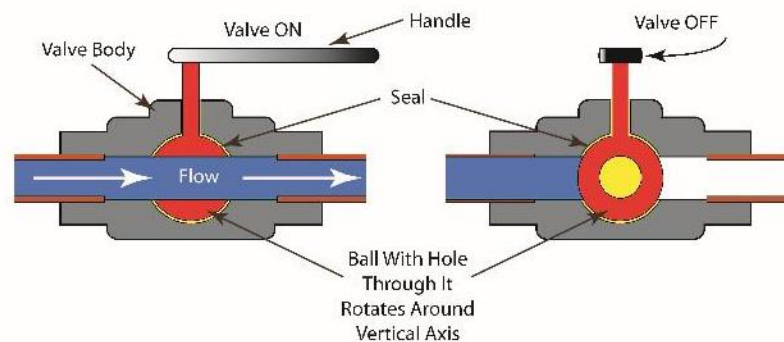


Figure 1-13 Web Diagram of Ball Valve Showing Shutoff by Rotating the Ball in the Seat

I understood the utility of this ball valve flow control method in the industrial PU machines, I wondered if there was a way to use this in the portable kit dispensers. This process has always been the same for me; I mentally debate the merits or pros and cons of an idea as I think about the possibilities of an idea and challenge it with the demands of a problem, reflectively judging the merits of an idea as it evolves in my head. This process has always preceded my design evolution towards a solution. Strategically this design cognitive modelling is necessary to bring focus to your efforts to efficiently and effectively solve the problem (see Figure 1-14).

Case History 1 – Insta-Flo Dispenser

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 1-14 Connecting of Traditional Ball Valves for a Possible Two Component-Metering Dispenser (Images From Web)

1.6.4 Creation of the Spool Valve Design:

Understanding the A Component constraint, I wanted to determine if I could somehow build off an existing ball valve method that was proven to work in the PU machinery I used in manufacturing plants in my past experience with success. To move forward I needed to research and understand what was it about the valves that I could learn from and build a new style valve out of what worked. Ball valves were not new; in fact, they were very common, so why had they not been used previously in this hand held dispenser application? The existing ball valves were all designed to act independently for controlling flow. Reframing this paradigm, I had an application where the valves not only had to work in tandem, but simply and precisely to both control and accurately meter the flow of the A and B components. Ball valves were not traditionally considered metering valves, as the needle valves of the Finn patent were. The solution required a reframing of the common thinking about valves.

Case History 1 – Insta-Flo Dispenser

Mental Model of Ball Valve Style Problem Solving

Addressing the Root Cause

Ball Valve Idea Mental Modeling

Work with Isocyanate (constraint), check valves sticking	Ball valves are common in plant production equipment, have not been built in tandem spool style
Eliminating pushrods to stop leak path & dead space	Ball valves work by rotation not by linear movement or pushing open
Ability to meter the components on ratio, adjust the flow rate while maintaining ratio	Possibly, I had seen ball valves meter before, could connect two in tandem
Eliminating dead space passageways exposed to air-moisture that could clock material flow	Possibly, depending on how they were used in the relation to the material supply and the nozzle for mixing pathways
Connecting the valves in some way to eliminate the lead lag	Yes, I had seen the ball valves connected on earlier version of in plant equipment
Minimizing or eliminating leak passageways	Yes, ball valves had well adapted sealing technology in practice

Figure 1-15 Mental modelling of ball valves as a solution to the nozzle design problems

Based on my reflection on the ideas and my mental modelling and judgement (dialectic process), I believed that the ball valve model could possibly work. I knew this style worked with in-plant production equipment. My next steps were to think about how I could make this model work for a two-component dispenser in a simple and easy embodiment beyond the complicated and expensive plant equipment application.

My cognitive modelling next steps were to address the following questions:

- Could I create valves that were small enough for a handheld dispenser?
- How could I connect the balls so that they worked in unison?
- How could I rotate the connected valves to open and close easily?
- Could I rotate the valves comfortably in the range of a hand-held device?
- Could I create a valve body that would not leak?
- Could I connect two incoming hoses to the valves?
- How could I seal the valves in the body without exposing to air?
- Could I use the existing mixing nozzle design with the two nozzle inlets?
- Could I eliminate passageways after the valve shutoff?
- Would allow me to protect this design as Brooks did with his?

Case History 1 – Insta-Flo Dispenser

My mental modelling journey continued, seeking a way to address these questions to address the needs for a design that could work based off this model. Envisioning tandem ball valves connected to each other and have connections extending each side for a handle to connect and rotate, I began sketching and working on ways to package this into a dispenser body and create seals (see Figure 1-17).

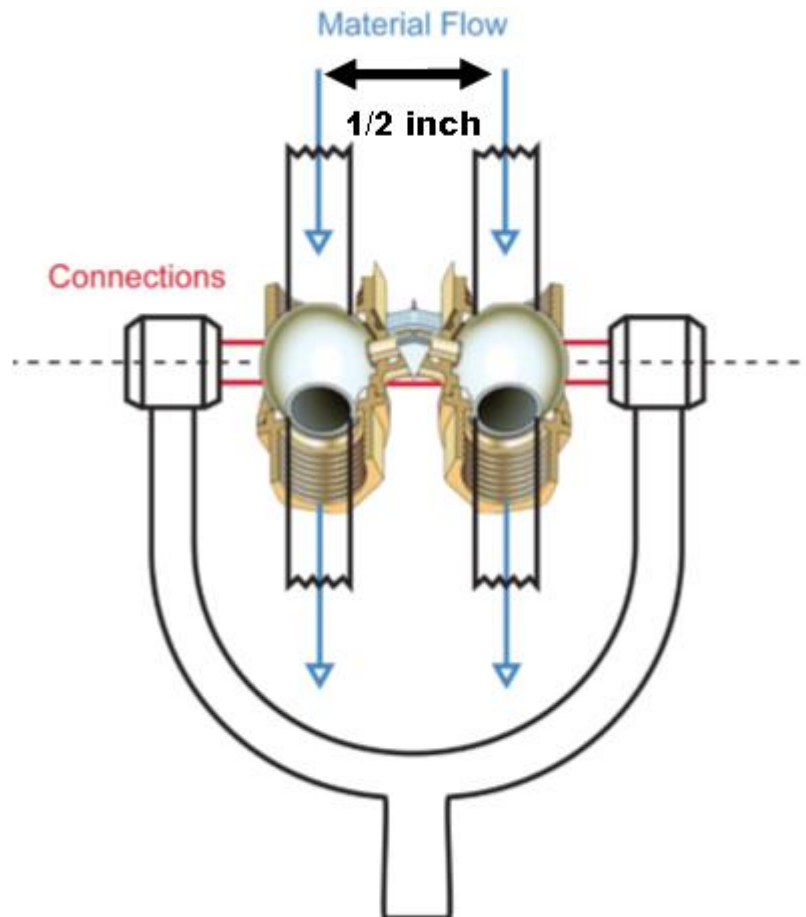


Figure 1-16 Ball Valve Images from Web Manipulated in Tandem Alignment

Working on how to package the dual rotating ball valves into the body, and create seals for each of the valves that would fit in the body constraints of the existing nozzle challenged me to envision ways to minimize the size of the valves and seats of the traditional style. I had envisioned using these valves in a straight-line flow path so that the components would flow directly from the hoses into the back of the mixing nozzle with the minimum amount of passageway (see Figure 1-18).

Case History 1 – Insta-Flo Dispenser

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 1-17: Image From Brown Patent

While this straight flow path was the simplest route for the components into the nozzle, it presented some challenges for sealing the ball valves in the traditional way. First, the material flow passageway had to be sufficiently large not to restrict flow and be easily machinable, but small enough not to create stack-up sizing that would prohibit the use of the existing nozzles, which the management insisted on using. The existing nozzle production was in itself a significant investment and infrastructure and the management did not want to tackle a redesign in this area at the same time. An additional constraint was to use the existing nozzles where the major restriction was that the centre-to-centre distance on the flow path was 0.5 inches. Thus, I would need to have dual activating ball valve package that seals and simultaneously activates with centre-to-centre flow paths of 0.5 inches. Not much room for the conventional seats and seals of ball valves (see Figure 1-19).

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 1-18: Combined Web and Patent Images of Ball Valve Idea

While the idea of ball valve style metering of the components had merit, the packaging and arrangement of the valves and seals to work with the existing nozzle

Case History 1 – Insta-Flo Dispenser

provided a significant sizing challenge. In addition, the seals-seats, connecting elements to join the valves in tandem and to connect to the trigger all were creating compounding challenges. The primary issue was that in order to have ball valves next to each other with a 1/2 inch material flow path would require ball valves with a maximum of 1/2 inch diameter including the seal-seating elements, at best this would allow for 1/4 – 3/8-inch ball valves. This is very small for this style valve, I needed to find a way to accomplish this valving but reframe the sealing and connecting of the valves.

The design challenge at this stage of the development process was not new territory for me. From my experience, I knew that I often would confront these confusing situations on my pathway to a new solution. This is not clear or comfortable position to be in, but as described above, the cognitive design mental modelling process can drive you to the knowledge gap in a systematic way if you follow the resolution to the problem. A metaphor would be a chess game played by highly proficient chess players who are forced to not only make the current move but they are mentally modelling the response of their opponents and future moves while they are making their current decisions.

I was immersed in this challenge, dreaming about the competing interactions at night, and sketching and mentally modelling the interactions of all the components during the day. After a few weeks, I had the inspiration to use a spool-shaped valve with two holes on 1/2 inch centre-to-centre alignment (existing nozzle constraint). Instead of connecting two independent ball valves, this totally simplified my challenge and was adaptable to the smaller body size I needed to use for a hand-held device (see Figure 1-20).

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Case History 1 – Insta-Flo Dispenser

This inspiration allowed me to:

- Eliminate pushrods
- Meter the components
- Connect the valves
- Minimize or eliminate leak passageways
- Fit the valving design into a small dispenser body
- Utilize the existing nozzle with ½ inch flow paths

Today when I teach design, I emphasize to my students that it is precisely this total emersion into the design challenge that brings focus to the key drivers at the existing knowledge gap. Intense research and focus puts you at that interface of synthesizing new knowledge when the existing knowledge falls short. While I felt that I was on to a possible breakthrough solution, my design challenge was not over, as I had to design a new sealing-seating method for this concept.

I had three primary challenges at this stage:

1. How do I seal the passageways that would now share the same bore that accepts the spool from the A and B components?
2. How do I seal the face of the spool where the material supply chamber terminates prior to the valve?
3. Was there enough of a relationship for the valve rotation to both create a seal in the off position when rotated but be comfortable enough so that the operator could reach the handle when the dispenser was off and activate the dispenser?

1.6.5 Sealing the Spool Valve

One of the more difficult challenges for these dispensers was creating seals that did not allow leakage, especially the A component leakage that would quickly harden and block the passageways. Complicating the fluid seal was the fact that there were liquid blowing agents compounded into the components that expanded on pressure drop when dispensing. The seals were more similar to sealing gas versus a liquid, which is considerably more challenging, and leakage of the blowing agent would be a kit failure as the kit pressures which were balance for maintaining ratio would be off and thus the foam ratio would be off creating bad reacted PU foam.

While my inspiration was a ball valve, my spool valve adaptation was more challenging to seal. Ball valve uses ball seats made out of a plastic deformable material that conforms to the round surfaces, creating a lot of surface area for the

Case History 1 – Insta-Flo Dispenser

seals. The round surface of a ball also interacts with the cup of the seal to reinforce the seal under loading. The trade-off is if you have to put too much of a load on the seals, they make the valves hard to rotate. This is not good for a dispenser that you want to operate by hand, and automatically close with a spring force. Thus, I needed to seal both passageways with the minimal amount of force, but at the level of sealing a gas at 250 psi. Sealing was now a critical challenge.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 1-20: Comparing Ball Valve Sealing and Spool Valve Sealing Surfaces

Traditional ball valve seats captured the ball in a three dimensional symmetrical encapsulation, the spool was round in one plane but linear in the other unlike the ball valve. This provided both an opportunity and challenge, for the seal between material pathways within the bore; I was able to use a highly reliable and conventional sealing technology. I designed the spool to have O-Ring seals (see Figure 1-18 # 47) that separated the A & B flow paths across the length of the spool to avoid crossover and as a backup to gas leakage where the spool exited the body. I designed the spool fit snugly into the dispenser body, as it was plastic, but not too tight to restrict rotation. O-Rings are inexpensive and reliable seals; another material choice consideration. A trap when choosing components such as O-Rings, it is important to use O-Rings made from rubber that is not chemically degraded by the materials you are working with. Many unseen traps such as material compatibility, duty cycle degradation, and tooling where must be considered in the design process.

Case History 1 – Insta-Flo Dispenser

The next challenge was that my material flow path had to be sealed on the spool faces and I designed Teflon seats that were derived from traditional ball valve seats out of Teflon (see Figure 1-22, #'s 66 & 68). These Teflon seats needed to maintain a constant compressive load on the seals; I used sealing screws behind the seats that could be adjustably set during assembly with a fixture that provided pressure to the seat (see Figure 1-22, #'s 72 & 74).

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 1-21: Drawing of Spool Valve and Teflon Seats 66 and 68 from Brown

Complicated by the fact that I needed to seal on the face of the spool without the typical 90-degree rotation of a ball valve, as can be seen in see Figure 24, the rotation is not the full rotation of a ball valve, which provides more sealing area. A 90-degree rotation on this design would cause the handle angle to swing excessively far forward for a practical hand held dispenser. Causing the handle too become difficult to manage in an operator's hand (see Figure 1-23, # 24). The advantage of the spool valve versus two separate ball valves coupled within the dispenser body eliminated for a separate coupling between the balls. Eliminating connecting within the body and the need for additional couplings on each side of the balls to engage the ball valve

Case History 1 – Insta-Flo Dispenser

assembly to the handles. The spool valve (see Figure 1-22, # 109) provided one machinable part the complete mechanical valve and coupling to the handle-actuator in one component. The spool valve design allowed for an elimination of multiple components, easier assembly, while also reducing the assembly complexity. This lean design strategy integrated into the evolutionary design process is critical, without the designer engaging in all of these decisions in a strategic chess-like what is the next move way, they often will not be addressed.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 1-22: Drawing of Handle Activation from Open to Close from Brown 437' Patent

The original machined seats were challenging to seal, but I had confidence that once I could mould the seats and optimise the Teflon choice I could seal the dispenser. The question was, how could I seal the dispenser with the less-than-ideal

Case History 1 – Insta-Flo Dispenser

spool valve rotation (less than 90 degrees) that ball valves relied on? This was a challenge where there were some uncertainties until we could build the tooling and get moulded optimised seats to test and validate the sealing interactions. Fortunately, after some continued optimisation of the moulded materials and the force loading on the spool, I was able to effectively seal the dispensers reliably in a mass production. At times, especially when pioneering new designs you can only work to raise the level of certainty of your proposition, until you can build and test the design under real world conditions. Navigating this lack of certainty when pioneering into new unexplored spaces is a strategic design process that must be integrated into your design strategy.

1.6.6 Creating and Testing the Prototypes

I began modelling and sketching possibilities for the dispenser; mental modelling and freehand sketches at first, followed by scaled sketches with dimensions on engineering paper. First, the valve, then putting the nozzle in front and the supply hoses behind (see Figure 1-20). In hindsight, it looks simple, but it is a very challenging exploratory and evolutionary iterative process. My first prototype sketches were quickly evolving as the challenge had captivated me. As I described earlier in this design quest was at first an unsanctioned project until I could demonstrate the potential of the idea.

Once I had the concept of the spool valve, everything started to fall in place. The spool valve allowed me to put the valving in a straight material flow path, a straight path is the shortest distance, and in this case, the straight path virtually eliminated open passages forward of the valve. Similar to a ball valve there is a passage inside the valve that concerned me if it proved problematic. I envisioned that when the rotation to the off position of the spool occurs, the path internal to the spool valve is sealed on both forward and rearward sides; in this case sealed from the moisture that would react with the A component (see Figure 1-24). During my mental modelling and sketching, I realised that I could put the disposable mixing nozzle nipples directly onto the front face of the spool, eliminating the passageway's dead spaces exposed to air-moisture when the spool rotated closed, even when the mixing nozzle was removed from the dispenser the passageway within the spool was sealed from moisture. This advantage was validated by testing of the early prototypes, and critical to the success of the spool valve design.

Case History 1 – Insta-Flo Dispenser

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 1-23: Drawing of Spool Valve in Closed and Open Position from Brown 437' Patent

Creating the prototypes to test the designs were their own significant challenge, but an essential part of the design process when seeking insights into new interactions do not have a performance history. As mentioned previously I had access to a machine shop with one of the most intelligent and skilled people that I have ever worked with named Jess Lukancik. Jess did not go to college but that did not stop him from achieving in life, he focused his skills on machining and became an expert at it. Jess mentored me in the machining processes and with his patience and guidance starting with this project, providing me with years of insights from his practise that I rely upon every day. Jess and I side by side built successive generations of prototypes of the spool valve design to first prove the concept and later to optimise the interactions. I am not sure that I could have accomplished this design had it not been for the machining and prototyping assistance of Jess. Even if I could I, know it would have been a much longer more arduous path.

From my past application engineering experience, I also knew that I needed to get the potential component suppliers involved with the design process as early as possible. For the spool, this was easy as it was a component that Jess could manufacture, but for the moulded components, I needed to similarly work with the injection moulder. A company who had worked with Brooks on the original design,

Case History 1 – Insta-Flo Dispenser

was moulding the current dispenser body locally and I immediately engaged the owner and engineer in the design process. I wanted to be sure that my design choices could be easily moulded or as I had to deal with many times previously in my PU moulding work, designers design components that cannot be produced. Part of this chess game is to achieve your design goals early on, but do so in way that your design choices do not eliminate your productisation ability when you get to that stage. This also applies for the manufacturing process, quality control standards, distribution channel requirements, performance standards as well as the generally understood user needs and requirements of the challenge. I see this as a stakeholder design process, arising beyond the user-centred design process, it utilises the same principles but extends the research and analysis across the consumption chain of the product experience.

1.6.7 Platform Design and Dispenser Design Improvements

Insta-Foam was a pre-established product line, and this line already had a number of variations of the portable kits developed. Beyond the size of the kit that the customer could purchase depending on the amount of PU foam needed for the job, Insta-Foam put a considerable amount of time and effort into creating custom foam formulations for specific uses. Below is a chart of uses for Insta-Foam, now Dow Chemical's Froth Pak Product line, which is built off the Insta-Flo dispenser of the Brown 437' patent.

Every US space shuttle that flew used foam dispensed by the Brown 437' dispenser, along with countless other applications including industry, residential and military. One unique use that was a tenement to the robustness and versatility of the design was an underwater use of the dispenser and kit to facilitate the raising of the Hunley, a Civil War submarine lost in action and recovered more than 100 years later as discussed in the documentaries below. The Brown 437' dispenser was instrumental in this salvage as attested by the interview with Bill Youmans.

The story of the raising of the Hunley can be viewed by searching "Raising the Hunley" on YouTube. There are numerous documentaries and videos about this story that I am very proud that my design made possible. The dispenser worked according to Bill Youmans underwater for over one month during this project.
https://www.youtube.com/results?search_query=Raising+the+Hunley

Case History 1 – Insta-Flo Dispenser

Product Sales Sheet Highlighting Some of the Many Applications

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 1-24: Worldwide Uses of Froth Pak (Dow Chemical)

The platform design strategy builds off the concepts of expanding your product offering by designing ways to sell more of your design in different but complementary configurations. The Insta-Flo dispenser was designed to be a component of a platform of many portable kits that allowed configurations of small kits to large in plant pressure tank usage of the same Insta-Flo dispenser to efficiently and reliably apply high quality poly urethane foam in many diverse applications. As in many of the other examples of this case history, the designer must think ahead to future platforms when designing the product, choosing the materials and manufacturing processes (see Figure 1-26).

Case History 1 – Insta-Flo Dispenser

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Case History 1 – Insta-Flo Dispenser

1.6.8 Updating the Dispenser

The Brown spool valve dispenser has been in the market for over 30 years, I have had the opportunity to update the design several times over the years. Although the original spool valve has stood the test of time, remaining the industry benchmark over the years. I believe this is a testament to the heuristic of getting to the root of the problem, which the dispenser addressed and seeking a novel solution when the existing knowledge of practise falls short.

Brown 245' US Patent below – Created a dispenser built of the Brown 437' that allowed for the development of a water blown portable kit system.

Brown 259' US Patent below – Redesigned the valve seat system to eliminate the Teflon seats for the dispenser, reducing components, and assembly costs.

Brown 468' US Patent below – Redesigned the safety system to eliminate the need to manually activate the safety, the safety works only when the dispenser is gripped properly for dispensing, otherwise the dispenser will not dispense.

Brown 185' US Patent below – Redesigned the valve seat system to allow for variations in ratio and meter rates based on seat geometry.

Case History 1 – Insta-Flo Dispenser

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 1-26: A Design Evolution that Allowed for a Third Stream of Air to Spray the PU Foam

Case History 1 – Insta-Flo Dispenser

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Case History 1 – Insta-Flo Dispenser

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 1-28: A Design Evolution that Allowed for an Integrated Dispenser Safety

Case History 1 – Insta-Flo Dispenser

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Fig

atio

Case History 1 – Insta-Flo Dispenser

1.7 Reflection on Creating the Insta-Flo 2-Component Dispenser

The portable kit technology had the technical challenge of processing the A and B components in remote, uncontrolled conditions, while the necessity of maintaining foam quality. If the final reacted PU foam quality was not satisfactory, the whole effort to utilise this chemistry in portable applications was worthless. Thus the dispensing technology was challenged to not only utilise the technology in a portable kit, but also create quality polyurethane in the most reliable and efficient manner possible. Even in the controlled conditions of manufacturing plants, maintaining foam quality was challenging, as the A component was a constant source of processing issues. In plant, the A component would leak out of the drive shafts of pumps encountering the moisture in the air, and literally freezing off, seriously degrading a pump's performance overnight.

As noted in the Brooks 551' (1978), Finn 694' (1985), and the Brown 437' (1987), the A component would harden up like plaque in an artery in the process flow passageways. The Brooks and Finn designs employed traditional approaches to cleaning process passageways with traditional flushing means adapted to the foam dispensers. The intense reactivity of the "A" component, which was an essential nature of the material for the two-component reaction, was the reason the conventional engineering practises and knowledge fall short of eliminating the problem in the portable kit business.

In addition, there were other unaddressed functional needs of the users of the existing Insta-Foam Brooks's 110' dispenser that were identified in the Brown 437' patent. These needs were researched and identified in a thorough problem and need finding and framing process, this process started with an investigation of the existing dispenser's performance and problems in order to learn and redesign based on those insights. A summary of the observed problems is below.

Case History 1 – Insta-Flo Dispenser

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

1.8 Reflecting on the Differentiation by Design Process

Reflection on the Differentiation as can be seen from the chart below (see Figure 1-32), the functional redesign of the dispenser as disclosed in the Brown 437' patent addressed all of the previously identified dispenser issues. This basic design is still in production today over 30 years later, although I have actually updated and expanded on the design, which I will discuss in the following sections. One note is that I put a dashed line over the “preventing nozzle backflow” as the spool valve did do this for the majority of situations. However, one scenario could occur where the user could continue to activate the dispenser with a clogged nozzle. If the user did introduce reacting materials into a clogged nozzle and continued to hold the dispenser open the pressure in the nozzle could still cause rearward flow into the dispenser creating a crossover. This user forced crossover condition, along with the introduction of a clear nozzle to see if the nozzle had been used was rectified, and is the subject of the second case presentation of this thesis.

Case History 1 – Insta-Flo Dispenser

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 1-30: Chart Summarizing How Design Addressed the Problems

1.9 Reflection on the Business Solution

The development of the Insta-Flo dispenser that resulted in the Brown 437' patent had several direct impacts on Insta-Foam Products business. The dispenser was designed, tested and brought to market in less than a year and had an immediate impact on the business.

- First the dispenser quickly countered the threat that the Finn 694' dispenser was posing to the Insta-Foam market share.
- Customer complaints dramatically decreased and the cost associated with product claims dropped significantly.
- The use of the dispenser by novice users expanded greatly, a valuable product only used once by trained professionals because of the difficulty of use has evolved into a product that can be purchased today at all the major Home Centre stores to be used by consumers.
- The dispenser costs decreased by greater than 50%, and reliability was no longer an issue or the weakness of the portable kits.
- Users could now meter the flow of the mixed product allowing for a cleaner and safer use.

Case History 1 – Insta-Flo Dispenser

1.10 Conclusion

The development of the Brown 437' dispenser and the evolution of the design over the years is a case of how design must evolve into a new paradigm-changing concept when the existing knowledge and practise fall short of solving the problem to the customers' expectations. As can be seen in this case, the existing Brooks 110' dispenser pioneered the product category and acted as the cornerstone for the business. For sure it had issues, as almost all new technology does, but the product provided a significant amount of utility for the users, that they were willing to deal with the problems. When a new product appeared on the market as the Finn 694' dispenser, the situation immediately changed as users now had a choice between the Brooks 110' and the Finn 694' dispensers. Finn was competing and winning business, and the once dominant Brooks dispenser was losing. This is a situation of classic paradigm change, fortunately for Insta-Foam there was a sufficient base of users who had an endowed relationship with the product and the relationships in the distribution system. This endowed set of relationships and the resistance to change behaviour that established market leaders possess are powerful competitive advantages.

Case History 2 – Anti-X-Over Mixing Nozzle

2. Case History 2 – Anti- X- Over Nozzle Design and Development

2.1 Reflective Narrative History of the Anti- X- Over Nozzle Development

The subject of this case explores the design evolution of a family of two-component dispensers presented in Case 1 that created and pioneered a now mature product technology over the last 45 years. Early versions of the dispensers patented were created and patented by Bill Brooks, an inventor. These early dispensers patented by Brooks were based on traditional engineering applications of valve-metering methods in an attempt to solve the metering dispensing problem as discussed in Case 1. This Case takes place 10 years after Case 1, and focuses on the next generation and current embodiment mixing nozzle evolution for the polyurethane dispenser. The metering of the components of the dispenser integrate with the mixing and dispensing capability of the nozzle to provide a metering-mixing-dispensing apparatus. The mixing nozzle technology compliments the dispenser technology of Case one forming a low-cost metering-mixing-dispensing portable system that is the current industry standard.

This Brown redesigned system is still the marketplace benchmark, now 30 years after its invention. This case studies the development of a product known commercially as the Anti-Cross Over (Anti-X-Over) nozzle. Crossover in the Poly Urethane (PU) industry is a phenomena seen in the metering and mixing product of then the components of polyurethane reaction find their way back into the dispenser reacting and fouling it, rendering it useless in most cases. The relationships between Case 1 and Case 2 are inseparable, although the designed products are two separate instances of how design can create value and competitive advantage in commercial markets. While Case 1 is an example of a Design Engineering solution to a problem where the existing engineering technology fell short, Case 2 builds on this design process to also address unmet and unarticulated needs of the stakeholders in the process.

Polyurethane (PU) is a thermosetting plastic created by the reaction of a number of constituents blended into two main components. Polyurethane chemistry has a tremendous amount of versatility resulting in finished plastics ranging from lightweight foams (pillow foam, and foam insulation) to dense elastomers (roller-skate

Case History 2 – Anti-X-Over Mixing Nozzle

and skate board wheels). The particular focus of this product application (detailed in Case 1) was the creation of a portable two-component polyurethane creating kit that could be utilised at a remote job site without the need for additional utilities or equipment to create the polyurethane foam. The product goal was a “Foam Machine in A Carton” (see Figure 1-1, case 1). Evolving from the game-changing product of Case 1, this Anti-X-Over Nozzle case illustrates that the ultimate solution, now having competed as the dominant technology in the marketplace, resulted from a very different approach to the problem than earlier attempts. This approach can be described as a designerly process of enquiry into novel methods of solving the problem in unexplored novel white spaces, as opposed to the previous attempts to solving the problem utilising traditional engineering solutions. The spool valve of Case 1 in one example of a white space approach to this creative problem solving process.

This item has been removed due to
3rd Party Copyright. The unabridged
version of the thesis can be found in
the Lanchester Library, Coventry
University

Figure 2-1: Patent Image of Original Brooks Dispenser and Nozzle Apparatus

This second case builds off the first case history that described the redesign of the original Brooks dispenser (see Figure 2-1), further addressing the problem of material backflow from the nozzle back into the dispenser not completely addressed in the first case. As will be discussed in detail later, during the mixing-dispensing operation with the original Brooks nozzle, if the operator were to activate the dispenser with a clogged nozzle as inexperienced operators are prone to do, the forces from the reacting material in the nozzle can overcome the dispensing pressure of the components and reverse flow into the material supply paths of the dispenser. If this were to happen, the dispenser would be clogged with reacted material and rendered inoperable. When working on this problem we described it as intentional crossover.

Case History 2 – Anti-X-Over Mixing Nozzle

With the advent of the Insta-Flo Dispenser in the 1985, design of Case 1, (Brown 437' design) many of the issues with the dispenser crossover which had been eliminated. One continuing issue that was still possible was a particular instance of material forced or intentional crossover arising from inexperienced use, as the Insta-Flo dispenser was using a 20-year-old mixing nozzle design. Crossover is rearward back-flow of mixed material into the material passageways from the mixing nozzle into the dispenser. Ten years after the Insta-Flo creation, a mixing nozzle redesign opportunity appeared as the original injection moulding tooling had worn out after millions of cycles, I secured the project as an outside consultant to the company at the time. In a continuing effort to eliminate dispenser fouling, I sought to address this nozzle backflow problem, and eliminate any possibility of it occurring by redesigning the nozzle. As can be seen in US Pat. # 4,117,551 below, Bill Brooks attempted a nozzle anti-crossover redesign by utilising a traditional engineering solution in 1978 that did not work and was never productised. There was an opportunity to aspire beyond the basic updating of the product, but to seize the opportunity to redefine the mixing nozzle performance in the marketplace.

Bill Brooks, the pioneering inventor of the portable two component kit business and the predecessor inventor to a number of my product inventions, had also recognised this material backflow problem known as crossover and attempted a design to solve the problem in the late 1970's (see Figure 1-2). The Brooks design placed mechanical check valves in the mixing nozzle orifices. While this solution appeared logical from an air or fluid processing existing technology practise, it failed to work with PU components and was never commercialised. The challenge of the PU component chemistry combined with the fact that the size of passages was so small required that the ball and springs check valves to be unrealistically small to function. The unforgiving nature of the Isocyanate "A" Component chemistry created a new playing field for the mechanical design in these dispensers, as seen in Case 1. The traditional technical solutions to problems were insufficient in managing the highly reactive A chemistry. The root cause of problem was the A chemistry reactivity, but engineers were attacking the symptoms in their efforts to solve the problem. This can be seen in the addition of flushing systems as described later in the Brooks and Finn patents. As seen in the solution that has now stood the test of time for close to 30

Case History 2 – Anti-X-Over Mixing Nozzle

years was to eliminate the need for flushing by addressing the root cause versus the symptoms of the problem.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 2-2: Patent Image of Mixing Nozzle Back Cap with Traditional Check Style Valves

Brooks also intended this nozzle to be used with his updated dispenser flushing design of the 551' patent. While the flushing design of the patent was commercialised for non-portable foam applications as the Insta-Foam MG-3 dispenser, the miniature ball checks built into the nozzle ports were never able to become productised. The viability of incorporating a flushing system into the portable kit business was not feasible for the application. In 1985, a competitor of Insta-Foam named Versa-Foam introduced an updated competitive dispenser with a manual port to purge the material passageways with solvent once fouled (see Figure 1-4). The Finn dispenser also introduced the ability to easily meter the material output with metering valves. Thus, the metering was a desired need of the foam users and while the flushing included a number of extra steps and use of solvents, it was a workable recovery for a crossed-over dispenser in the field for portable kits. The Brooks original dispenser-nozzle apparatus had no such ability. This put the Insta-Foam market dominance in the portable kit business that they pioneered at great risk.

Case History 2 – Anti-X-Over Mixing Nozzle

Below is the Brooks 551' Patent describing his improved dispenser attempt to overcome these problems in the late 1070's. The patents thoroughly describe the problems that the users were facing in the marketplace.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Case History 2 – Anti-X-Over Mixing Nozzle

2.2 Benchmarking the Existing Solutions

The only existing solution for the crossover problem of the original Brooks dispenser (Brooks 110' Patent in Case 1) in the late 1970's was the Brooks 551' patent discussed above. This patent discloses both an integrated flushing system as well as a mixing nozzle with internal check valves to attempt to alleviate the material crossover problems in the dispenser passageways. The problem of crossover was thoroughly discussed in Case 1, and will not be repeated here.

2.2.1 History of Problem as Documented by Brown Patent US 6,021,961

Past experience has proven that there are some shortcomings to the old mixing nozzle design. In previous mixing nozzle designs there are circumstances that can occur during the course of mixing that create an opportunity for one or more of the reactants to flow rearward into the passages of the dispenser. This rearward flow creates or allows a condition of chemical reaction within the dispenser, causing the passages of the dispenser to be clogged with reacted material. This situation, commonly referred to as "crossover", is the major cause of product failure with these types of dispensing systems. When the passages of the dispenser system become clogged, the system is now rendered either completely useless, or at least useless to meter components "on ratio", due to the complete or partial blockages in one passage or another.

There are several common conditions that create the opportunity for crossover. One of the most common conditions occurs where the operator, upon first starting the operation of the kit, fails to open both supply lines to the dispenser. Thus, when the dispenser is activated, only one component enters the mixing chamber. At this time, there is no competing pressure or flow from the other supply port of the valve or mixer inlet, and consequently, nothing to prevent the single component within the mixer from flowing rearwardly out the other inlet passage and into the dispenser.

Once the operator realizes that only one component is flowing, he understands the problem. Then he opens the second supply valve and pressurizes the dispenser with the second, previously missing component. At that time the second component mixes with the first in the dispenser valve and hoses with the "crossed over" component, thus causing a reaction and fouling the dispenser.

A second situation occurs when the operator activates the dispenser with a previously used and clogged or partially clogged nozzle. At this time, and

Case History 2 – Anti-X-Over Mixing Nozzle

according to the pressure within the system at this time, the nozzle is charged with more reactants but the outlet passage of the nozzle is blocked. This produces a situation wherein the reactants are reacting and generating high pressures internally within the mixing nozzle.

Because the discharge tip is blocked, reactants cannot be discharged from the end of the nozzle, the reacting, and hence expanding material continues to expand forcibly within the nozzle. If, at this time, the operator pulls the trigger of the dispenser without ejecting the nozzle, a crossover condition arises due to the rearward flow by the reacting material into the dispenser. This rearward drive is created due to the higher pressure present in the nozzle when compared to the line pressure feeding the dispenser. Particularly when portable kits are used that are not full and/or at the highest pressure, the pressure created in this type of crossover within the nozzle can overcome the supply pressure and drive reacting material rearward into the dispenser, thus fouling the dispenser.

A third crossover condition exists as a result of simple pressure differences occurring between the two pressure streams, where one stream is strong enough to overcome the other, forcing a condition of rearward flow of the component that otherwise would be urged into the nozzle under the lower or weaker pressure. This particularly occurs if a new container is used with an old or nearly-exhausted one. This situation also arises when using supply pumps and there is a pump failure.

While relatively short time lapses between sprayings can ... permit the fluid constituents to either completely or partially solidify within the gun components, thereby completely or partially clogging the gun.

This problem of partial gun clogging during intermittent spraying operations can be minimized or eliminated by purging those parts of the gun wherein the fluid components are comingled, mixed and discharged with a nonreactive purge fluid.

In the 1995 time frame of this case, the existing solutions were primarily the Insta-Flo dispenser, the Versa-Foam Finn dispenser, and a recent market entrant the Fomo Products dispenser. The Insta-Flo dispenser had dominated the market followed by Finn dispenser.

Case History 2 – Anti-X-Over Mixing Nozzle

2.3 Description of the Design Challenge - Problem from Patent Records

2.3.1 History of Problem as Documented by Brooks Patent US 4,117,551

Excerpted from Brooks 551'Patent:

Experience has shown that the components of urethane foam can be selected so as to provide a relatively quick-hardening product fluid.

After the material is sprayed on or into the target area, foam product solidification begins. Now, this solidification occurs not only in the desired target area, but in residue product which may remain within the dispensing gun after spraying has been stopped.

Residue foam product which has hardened inside parts of the gun make gun cleansing and subsequent use difficult.

This problem has been met with great success by foam dispensing guns such as those disclosed in Brooks U.S. Pat. Nos. 3,633,795 and 3,784,110. In these devices, the foam gun is provided with a nozzle inside which the foam product constituents are mixed, and from which the mixed foam product is dispensed. After gun use, the nozzle can be removed, and a fresh nozzle installed.

Recently, the use of urethane foam as an insulation and packing material has found increased favor in applications providing target areas of restricted size and shape. When workers are dealing with such restricted target areas, they often find it necessary to spray or apply the foam in an intermittent manner.

Under such circumstances, it may be inconvenient to remove and replace a spray gun nozzle after each short spraying operation. A number of short spraying operations may be required during a single packaging or insulating job, and repeated nozzle replacement can add to costs, and can delay production.

While relatively short time lapses between sprayings can, under some circumstances, be tolerated without foam set-up and gun clogging, time lapses of greater duration permit the fluid constituents to either completely or partially solidify within the gun components, thereby completely or partially clogging the gun.

Poor gun performance and an insulation or packing job of degraded quality result. Worker annoyance and hurried efforts can also occur, and can indirectly contribute to a finished product of less than maximum quality

It is an object of the present invention to provide an improved dispensing gun for mixing and discharging fluids such as urethane foam.

Case History 2 – Anti-X-Over Mixing Nozzle

Another object is to provide a fluid mixing and dispensing gun wherein the problem of fluid solidification within the gun can be economically minimized or obviated even when the gun is used intermittently during short, spaced apart periods.

Yet another object is to provide a spray gun which permits purging settable product fluid constituents from important gun parts.

Still another object of the invention is to provide a dispensing and spraying gun for polyurethane foam and like products wherein relatively complete purging of both the nozzle and relatively upstream gun portions is assured. A more specific object is to provide a dispensing gun for urethane foam and like fluids wherein the fluid components and product can be easily and quickly purged from gun valves, the mixing nozzle and other parts thereby obviating clogging.

Yet another object of the invention is to provide a gun for mixing and spraying polyurethane foam and like fluids which can be easily purged when the gun is being used for intermittent spraying, and which is provided with a nozzle member which can be easily removed and quickly replaced after the completion of major-length spraying operations.

A further object is to provide a gun of the described kind which is inexpensive in initial cost, and which can be easily and effectively operated by even inexperienced personnel.

And a further object of the invention is to provide a mixing and dispensing gun for polyurethane and like products wherein interaction of the respective components is positively restricted to a disposable or reconditionable nozzle (Brooks and Heinzl 1978: col. 2; bullet points inserted for clarity).

This item has been removed due to 3rd Party Copyright.
The unabridged version of the thesis can be found in the
Lanchester Library, Coventry University

Figure 2-4: Material Flow Passageways Highlighted From Brooks Patent Drawing

While this patent describes the primary problems that Case 1 addressed, the problems are interrelated so the data is presented again in this case. The Brooks Patent 551' was attempting to address the field failure of the material crossover

Case History 2 – Anti-X-Over Mixing Nozzle

problem that was thoroughly described in Case 1 (see Figure 1-4). This case focuses on the last point of the 551' Patent excerpt above “[And a further object of the invention is to provide a mixing and dispensing gun for polyurethane and like products wherein interaction of the respective components is positively restricted to a disposable or reconditionable nozzle. This Brooks nozzle design can be seen in \(see Figure 1-2\)](#)”

While the ultimate root cause to the dispenser fouling problem was a combination of the fundamental nature of the A component chemistry and its reactivity even with atmospheric moisture. Additional causes arose from, the operator error encountered in the marketplace, and the nature of the use of the product which was intermittent as the workers were on the job insulating pipes and tanks having to often start and stop the dispenser during use. It is my observation that Brooks chose to pursue a traditional engineering solution of adding a flush to the dispenser, and integrating very small check valves into the nozzle in Case1, and the Insta-Flo design pursued a non-traditional approach for the solution. While the flushable dispenser did enter the marketplace as a system to use foam in plant operations where the additional flushing did not affect the portability. The nozzle design with the miniature check valves did not materialize, Brooks has since passed on thus I was unable to verify this but I believe that the size and dynamic interactions of the foam processing would never allow for these mini check valves to work in a scaled up mass production of a low-cost disposable mixing nozzle design. The existing engineering knowledge simply fell short in this situation. The redesign required a new approach to the problem.

2.3.2 History of Problem as Documented by Brown Patent US 6,021,961

[The present invention relates generally to mixing and dispensing nozzles, and more particularly, to a so-called anti-crossover or crossover-resistant nozzle for use with multi-component systems, particularly urethane foams. In particular, the invention relates to readily attachable, disposable nozzles having two principal pieces that snap together, and two more additional pieces or components making up the entire nozzle. According to the invention, the nozzles can be reusable with a non-reacting foam or may be used again by flushing with solvent. Such nozzles, according to the invention, have both an anti-crossover feature and a snap-together assembly and are associated in use with a dispenser such as a foam gun for dispensing foam, or other device for dispensing a bead, spray or fillet of a foam insulation or like material.](#)

Case History 2 – Anti-X-Over Mixing Nozzle

In the prior art, a number of nozzles have been available for use with such dispensers, (most of which are commonly referred to as guns). However, most if not all of such nozzles did not have an inherent feature which prevents so-called crossover in use. Neither were they a moulded, snap-together type construction. In a two-component urethane gun, both the isocyanate component and the resin component are metered under a supply pressure to a disposable mixing nozzle. Such a device, for example, was made by the assignee of the Brooks U.S. Pat. No. 3,784,110, which was the first commercially successful two-component foam gun having a disposable or throwaway nozzle.

A disposable low-cost nozzle is important for multi-component mixing and metering systems, because after a short time, (from one-half a minute to two minutes), the components making up the mix or other thermosets react to cure and set up in the nozzle, and thereby render further mixing, particularly on ratio mixing of reactants difficult or impossible.

Once used in a properly functioning gun, the mixing nozzle is simply removed and thrown away. This technique avoids the use of costly, and potentially harmful solvents for flushing.

In one use, the isocyanate component and the resin component are simultaneously admitted to a mixing nozzle in a predetermined ratio. This ratio is determined by the design of the system, chemistry of the reactants, and particularly by the size of the orifices leading into the nozzle passages, and by the supply pressure under which the components are maintained.

In one method, which uses aerosol type reactants, when the dispenser trigger is actuated, two valves open simultaneously and a desired proportion of each component is injected by the material supply force through the nozzle orifices and into the mixing and dispensing nozzle. Upon entering the mixing and dispensing nozzle, both the materials instantaneously experience a pressure drop, causing the gas in the material to expand rapidly as it passes along the mixing elements of the mixing nozzle. This expansion of materials creates turbulence and continues to mix as the reactants travel forward along the mix path of the nozzle. This mixing initiates a chemical reaction between the components, which causes the reactants to polymerize.

As the polymerizing mass exits the nozzle, it is under great force due to the supply pressure, vaporization of the blowing agents, along with the energy and gas generation created through the polymerizing reaction. Upon leaving the nozzle, the discharge pattern of the reacting material can be defined and controlled by any of a number of nozzle geometries resulting in a high force spray pattern, or a much lower force-pour pattern, depending on the application.

Case History 2 – Anti-X-Over Mixing Nozzle

2.4 The Knowledge Gap

In 1995 while the Insta-Flo dispenser itself was 10 years old it was using the original mixing nozzle design of the 1970's. At the time the dispenser reliability was not an issue for the stakeholders, the kit business had grown significantly over the past 10 years, since the introduction of the Brown dispenser in 1985. This redesigned Froth-Pak system allowed for more inexperienced users to use the kits without failure, and the nature and versatility of the portable PU kit business that Brooks envisioned was continually growing. The impetus for this project arose not out of market demand but the reality that the tooling for the existing nozzles was wearing out creating manufacturing problems. In addition, the manufacturing process for the nozzle had not changed in 20 years and was finicky and very labour intensive making the mixing nozzle cost high. While a mixing nozzle may in reality be low-cost, the fact that some applications required 15 to 20 nozzles because of the starting and stopping of the dispensing caused the nozzle cost to add up. Thus, the primary goal of the management was to replace the existing nozzle with new tooling and address the manufacturing cost at the same time.

While the re-tooling of the existing mixing nozzle would be a straightforward project, the need to redesign the manufacturing process and lean out the production and costs were the main design focus for the project. An additional and what ended up being the defining focus and identity for the redesigned mixing nozzle was an additional less obvious need that I was intimately aware of with the existing design and discussed later in this case. That need was to design a way to incorporate a technology that would prevent material back-flow into the Insta-Flo dispenser when an operator has the valves open but is trying to dispense with a clogged nozzle (forced crossover). Thus, there was an existing knowledge gap with the current solutions, how can a meter-mixing dispenser be designed to eliminate the forced crossover problem for all users?

2.5 Reflection on the Problem as Documented by Brown Patent US 6,021,961

The crossover problem was greatly reduced by the introduction of the Brown dispenser design that entered the market in 1985 with the Patent issued in 1987. The

Case History 2 – Anti-X-Over Mixing Nozzle

introduction of the Brown dispenser was such an improvement to the existing portable kit dispensers that it raised the expectation bar of the users for portable foam kit performance. In addition, the new dispenser allowed the kit to be used by less experienced operators, that combined with the versatility and benefits of portable PU kits drove a significant increase in portable kit usage beyond the traditional professional insulation marketplace. While the demand for the kit usage was apparent previously, the failure rate of the kits with inexperienced users prohibited the kit usage from expanding into other market areas. This changed with the introduction of the Insta-Flo dispenser of the Brown 579" patent (see Figure 1-5), and the kit usage expanded greatly. While the crossover problem had virtually disappeared, there was still some issues associated with the new dispensing system which relied on the original 1970's Brooks-designed nozzle.

.
This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 2-5: Brown Dispenser from 1987 -437' Patent with Brooks 1970's Mixing Nozzle

Thus, the new dispenser had successfully fought off the Versa-Foam Finn dispenser-based kit and re-established Insta-Foam as leading technology in the marketplace (see Figure 2-5). The reliance on the old mixing nozzle for the new Insta-Flo dispenser, which was a design constraint of the management of Insta-Foam at the time, now rose as the source of issues with kit failure. The apparent success of

Case History 2 – Anti-X-Over Mixing Nozzle

new dispenser did not require the attention for redesigning the mixing nozzle until the mid-1990s' when the tooling for the exiting Brooks 1970's version mixing nozzle was wearing out after millions of parts had been produced on it. At that time the Insta-Foam management decided to take the opportunity to redesign the mixing nozzle primary to increase the quality and reduce the manufacturing costs of the existing Brooks mixing nozzle. Acting not as an employee but an independent product design and development consultant and I was given the opportunity to now redesign the mixing nozzle for the Insta Flow dispenser that I had designed some 10 years ago.

Having in-depth knowledge of this technology, and insights into the performance and limitations of the current portable kit technology, I saw this as the chance to finish the design work of the dispensing system that I began in 1985. While the existing kit was performing without major issues in the marketplace, I knew that if I could seize this opportunity to design an anti-crossover feature into the nozzle during this redesign as Brooks had attempted in 1978, then the dispenser-mixing nozzle system would be virtually error proof. This would allow for a more tolerant kit that could be marketed to an even broader market, as the performance would not have to be as dependent on specially trained operators as was the case for most of the sales that time. The kits were sold primarily to contractors with experience using them, and after the 1985 Brown redesign, the complaints of dispenser failure had vanished.

I envisioned a kit that could also be used by the general public, sold at retail for home use for insulation, void filling and flotation, among many other uses. I knew that in order to sell into this consumer marketplace beyond the professional marketplace, the elimination of dispenser failure due to user forced material crossover had to be addressed as the. This nozzle redesign project that was basically cost reduction driven by the management for me was an opportunity to reduce costs, improve the nozzle ergonomics and most importantly create a nozzle that was crossover resistant to compliment the Brown dispenser redesign of 1985.

This project is an example of how seizing the opportunity when it presents itself can lead to unexpected success. While arguably it was my past deep experience with this technology that lead me to the insights of the needs for seeking to create an anti-crossover version of the nozzle during the redesign. I have found in my product design practise when I lacked this experience, my design process required that much deeper immersion and upfront research of the problem, the stakeholders and unmet needs

Case History 2 – Anti-X-Over Mixing Nozzle

of the challenge. This research is a critical and necessary upfront process for all design challenges seeking to create value and competitive advantage through identifying and addressing unmet stakeholder needs. Discovering through research those unmet needs can also provide insights into opportunities where existing solutions fall short.

2.6 Reflection on the Needs

In the mid 1980's both the Brooks and Finn dispenser designs were subject to crossover failures. The original Brooks dispenser simply failed, the flushable dispenser had some recovery ability and Finn had designed a dispenser with access to flushing port that users could maintain and recover a clogged dispenser for Versa-Foam. At that time, the Finn dispenser was attacking the Insta-Foam portable PU kit established marketplace as the Brooks flushing design did not work on portable kits, while the Finn design did so. Brown as discussed in Case 1 redesigned the original Insta-Foam Brooks dispenser and succeeded in virtually eliminating most all unintentional crossover and dispenser maintenance requirements, although there was one instance of intentional crossover condition that could still occur with Brown's redesign.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 2-6: Brook's 1970's Nozzle

This 1970's era nozzle was made from white styrene plastic, it consisted of three pieces (see Figure 2-6):

1. A back cap designed to snap into the dispenser body
2. A helical mixing nozzle
3. A front tube that slipped into the back cap with various tip designs to change the spray patterns

Case History 2 – Anti-X-Over Mixing Nozzle

The original mixing nozzle itself was a very simple design by Brooks, and the method of inserting the male mixing nozzle protrusions into the dispenser body was critical to the ease-of-use of the dispenser. This actually was a key element of the Brooks design and patent claims, which Insta-Foam succeeded several times in court proceedings to stop infringers. One of the main existing user problems with the nozzle was indirectly created by the manufacturing process. The plastic used to mould the original nozzle parts was white styrene, and although chosen at the time for manufacturing considerations, the white nozzles made it very difficult to see if the nozzle had been used. The lack of ability to see if the nozzle had been used would prompt an inexperienced user to assume it was a fresh mixing nozzle and attempt to apply foam but the nozzle was blocked. The nozzle was also assembled using a sonic welding technique which although simple was also problematic as there was no easy way to access the quality of the weld to insure a leak free and strong bond between the back cap and the front tube. Thus in production the nozzles had to be 100% hand checked, as a bad bond would create a mess and safety issue during application.

Dispensing into a blocked nozzle created bit of a pressure bomb within the nozzle as the foam could not dispense forward thus the pressurised mixed material flowed rearward. The experienced operator would recognize this and quickly eject the nozzle. For the first generation dispensers this would often have fouled the dispenser, as a crossover would have occurred immediately, with the redesigned Brown dispenser there was much more reaction time because the valve closed immediately behind the mixing nozzle ports preventing a backflow into the dispenser (see Figure 1-7, # 46). This is why the majority of the crossover failures were eliminated, as experienced users immediately recognised the problem and ejected the nozzle, and the Brown redesign did not have any passageways beyond the valve to get clogged. However, an inexperienced user would instinctively continue to try and dispensed foam with a clogged nozzle.

In this scenario, the continued activation of the dispenser by inexperienced users would open that valve behind the mixing nozzle and allow the higher pressure material to then backflow into the dispenser. The residual problem of mixed material being able to backflow from the nozzle into an activated dispenser we called forced crossover, and is what would happen when an untrained operator would attempt to with a clogged nozzle and they did not see any foam come out. It happened very

Case History 2 – Anti-X-Over Mixing Nozzle

rarely with trained operators, as they recognized the situation. Thus for the kit to become useful in the consumer market I knew that the ability for an inexperienced operator to recover from forced crossover needed to be eliminated. From my experience and analysis, as well as what Brooks had attempted in 1978, the solution resided in designing a wall to eliminate the possibility of any rearward flow out of the mixing nozzle into the dispenser. This became the primary focus of my mixing nozzle redesign and the other needs were subordinate to that for me for this project. Of course, I intended to optimise the other manufacturing and ergonomic aspects of nozzle use at the same time, but I first had to create a way to stop the back flowing.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 2-7: Brown Patent Image - Spool Valve Closing Immediately Behind the Mixing Nozzle Orifice

Summary of Stakeholder Needs According to Brooks Patent 551'

- Improved dispenser for mixing and discharging urethane foam
- Elimination of material solidification within passageways
- Provide a nozzle that can tolerate intermittent spraying
- Provide a purging system that can be quickly and easily used
- Provide a purging system that cleans passageways and nozzles
- Provide a low-cost dispensing system
- Provide a system that can be easily operated by inexperienced personal
- Provide a nozzle design that is disposable or reconditionable
- Provide a mixing nozzle design that restricts the components to the mixing nozzle. (my verbiage would be to prevent the backflow of material)

Case History 2 – Anti-X-Over Mixing Nozzle

As previously stated, most of these needs were addressed by the design of the Insta-Flo dispenser of Case 1. The additional needs to be addressed were redesigned in Case 2.

Summary of Stakeholder Needs According to Brown Patent 961'

- Improved anti-crossover or crossover-resistant nozzle
- Readily attachable and detachable
- Disposable or reusable depending on the application
- Simple low-cost snap-together assembly
- Provide an improved mixing and dispensing nozzle
- Not described in the patent there was the major stakeholder requirement of the project to increase quality and reduce the cost of the nozzle.

While the patent focuses on the invention-related needs, as discussed previously this project started as a Lean Re-Design for Assembly and Manufacturing of the existing mixing nozzle design. The insights of unmet needs further focused the project needs to also focus on seizing the opportunity to create a mixing nozzle design that eliminated material back-flow from the dispenser, the root cause of the crossover failure.

2.7 Bringing Focus to the Design Process

2.7.1 Getting to the Root Cause of the Problem

For this design challenge of eliminating backflow from the nozzle, the root cause reasoning was basic. Beyond the improvements to the dispenser and mixing nozzle assembly in Case 1 that had contributions to failure and recovery from failure during crossover the focus for this design challenge was straightforward. The mixing nozzle inlets had to prevent material from back flowing to the dispenser. Brooks had identified this cause in 1978 and attempted his design solution by using traditional check valves in the nozzle inlet ports (see Figure 2-2). The challenge for this design project was to design a way to do this within all the other constraints of the project where the existing knowledge attempts of operator training, flushing, and the Brooks check valve propositions had failed.

Case History 2 – Anti-X-Over Mixing Nozzle

Root Cause Design Opportunities

Problem Causes:		Design Challenge
• “A” Component reactivity	->	Constraint
✓ Blind Passageways	->	Eliminated in Case 1
✓ A & B Valves Independent	->	Connected in Case 1
✓ Pushrods source of sticking	->	Eliminated in Case 1
✓ Handle/Trigger is Weak	->	Strengthened in Case 1
✓ Ball Valves Do Not Meter	->	Metering Valves Case 1
✓ Cannot See If Nozzle Is Used	->	Use Clear Plastic
✓ Nozzle Backflow	->	Needs redesign

The ability to use a clear plastic for the nozzle front was not a great challenge as there were several commercially available resins that would work. Thus, the primary design challenge was to prevent the backflow from the nozzle-mixing chamber into the dispenser under all conditions, in addition incorporating this design into a robust Design for Assembly and Manufacturing strategy.

2.7.2 Designing the Backflow Prevention

In analysing the problem and reviewing the past failures to the situation, I realised that Brooks had focused on the correct pathway to success with his design, although he attempted to use an existing solution that was not suitable for the application. Brooks had chosen to pursue very small check valves that would be installed in each nozzle inlet orifice, this type of check valve was common in a larger physical embodiment in industry in a number of pneumatic and hydraulic applications (see Figure 2-8). Although the tiny check valves were beyond the reality of low-cost manufacturing of millions of nozzles with two of these small check valves in each nozzle. The complexity of tolerances for sealing and opening the ball check against the spring pressure needed to keep the valves closed were working against the application of this design. Although I was not present when Brooks attempted this work, I can appreciate how hard it would have been to make this design work.

Case History 2 – Anti-X-Over Mixing Nozzle

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 2-8: Brooks Backflow Prevention Design Using Check Valves

Pressure from material flow coming from the dispenser when the valves open would open the nozzle inlet passageways, pressure from the inside of the nozzles when there is a crossover condition or blocked nozzle would close the check valves keeping the blocked reacting material within the mixing nozzle. This system works on paper but was not suitable for the scaling, mass production and economics of a disposable mixing nozzle application.

2.7.3 Brown Patent 96' Anti-Cross Over Solution

The images below depict the early prototype solutions of the Brown 961' Patent plastic flapper valve design prior to the design for assembly and manufacturing needs described later (see Figure 2-9).

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 2-9: Patent Images of the Brown 961' Backflow Prevention Valve

Case History 2 – Anti-X-Over Mixing Nozzle

Understanding what had not worked, I set about researching the types of potential valves that could be used to prevent the backflow. I naturally wanted a simple and low-cost solution, as the design would have to scale for mass production. During my research, I started looking at how nature has managed these backflow situations and I thought of a heart valve, which has similar functional requirement of one-way flow. I knew that a heart valve used a series of flaps to open and close. These flapper valves were very functional and simple and I started to cognitively model how I could simulate this valving in the mixing nozzle (see Figure 1-9).

This item has been removed due to 3rd Party
Copyright. The unabridged version of the thesis can be
found in the Lanchester Library, Coventry University

Figure 2-10: Image Taken From Web Search to Illustrate the Action of a Heart Valve in Operation
http://img.webmd.com/dtmcms/live/webmd/consumer_assets/site_images/media/medical/hw/n5551209.jpg

My inspiration was to design a flexible plastic flapper that would sit on top of each nozzle inlet passageway allowing flow from the dispenser through the inlet, but not flow from the mixing nozzle to the dispenser. My first intention was to mould these flappers right onto the bottom of the mixing nozzle, and I had created variations of this out of plastic for testing that were proving workable. But when I engaged the idea with the moulder of plastics, he did not feel he could mould a combination of rigid mixer body with highly flexible and resilient flapper body out of the same material in the same mould. Although I wanted to combine these pieces for a simple assembly, the material properties would not allow it. I was looking for the performance of a plastic film out of an injection-moulded process. I needed a different approach.

My next alternative was to create the flapper valve separately from the mixing nozzle; this also simplified the prototyping process. My challenge was to find the right balance of film flexibility and stiffness to easily release for allowing flow but has

Case History 2 – Anti-X-Over Mixing Nozzle

enough memory to spring back to a closed position without the use of an additional spring. The credit for finding the right balance of properties goes to one of the owners of the plastic component suppliers named Clarence Schmidt (Schmitty), as he found that using a plastic with the properties of an old floppy disk seemed to work. I began prototyping the floppy disk based flapper valve using the existing mixing nozzles and the performance improved almost immediately. For testing and validation, I had to design and create a test apparatus that put air and water pressure through the front of the nozzle to simulate backflow. This fixture worked to quickly test various design alternatives and determine the promising combinations of materials and form. Having a workable solution at hand, I began to design a way to create these flapper valves for a mass production process. Beyond the plastic flapper design working in the field, the assembly and cost of these valves needed to meet the needs of the supply chain.

As this was not an established technology, I needed to source a way to make the thin film flapper valves. Hand cutting the valves out of the floppy disks had limited success, often at times leaving some ragged or bent edges that would interfere with the sealing. Therefore, I designed a stamping assembly and had it built by a toolmaker that would stamp the shape cleanly so that I could simulate a production quality valve for additional testing. I also found that during assembly of the prototypes that placement and orientation of the flappers was tricky. The film did not easily find its place in the old nozzle design and I had to find a way to keep it in place during production and usage. Finally, I had to find a way to handle all of these thin film valves during the production process that would be very similar to a woman putting on false eyelashes thousands of times a day, as each nozzle would require a thin film flapper valve.

The closest type of manufacturer I could find was a fabricator of plastic film components for medical applications.

Case History 2 – Anti-X-Over Mixing Nozzle

2.7.4 The Design Needs of the Manufacturing Process

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Manufacturing Design

Manufacturing component design requires involving the suppliers in the design process as early as possible. I have found that this strategy allows for the collection and analysis of the most amount of information for a successful project. I needed to address the following manufacturing issues with both the suppliers of components as well as the stakeholders in the nozzle assembly process.

Design for Assembly and Manufacturing Needs for the Plastic Flapper Valve

- In order to find and develop a new manufactured component I looked for similar components that were being produced for other applications. I found a manufacturer in Minnesota that had the core competency to stamp various plastics. I sent them a sample of the film from the floppy disk that I was having success with and they in turn sent me samples of films with similar characteristics that they had available for mass production.

Case History 2 – Anti-X-Over Mixing Nozzle

- This supplier had the capability to stamp and handle millions of film valves in an efficient and optimised way. This controlled the cost and quality of the valves, and I was able to use their specialized knowledge to optimise my design.
- The supplier suggested stamping and placing the stamped film valves onto a sticky roll, sort of a reverse-wound tape roll that would hold the stamped valves. This roll could be transported and easily used in production to feed the operator valves as they peeled them off the roll.
- This allowed the operator the ability to load a roll into a tape type dispenser and simply grab a valve with a tweezers to place in the back cap.
- The initial trials we had issues with static electricity and the film seating in the nozzle back cap. Attempting to resolve this issue of stabilising the film valve within the back cap after placement, I had the idea to put some adhesive on the valve in a certain area to hold the film in place during the production process (see Figure 2-11).
- After resampling this addition of an adhesive directly onto the valve solved the post placement moving of the valve in the back cap. It also allowed the manufacturer to simply place the valves onto a material transfer roll allowing the stickiness of the valves to hold them in position.
- Having an adhesive area and non-adhesive areas (see Figure 2-11) allowed for easier grabbing of the film valve with tweezers. Once grabbed off the roll for placement, they must be positioned into the back caps during assembly.
- In order to orient the valve easily for production, I designed the new back cap to have a cross-like cavity that tapered inward allowing for easily orientation and placement of the film valve into the back cap. I also added a centre post to assist in orientating the film check valve.
- For final anchoring, I added a cup at the end of the new mixer assembly that would capture the film valve tightly between the nozzle back cap and front tube by trapping the mixer between them.

Case History 2 – Anti-X-Over Mixing Nozzle

2.7.5 The Four Components of the Final Design

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 2-11: Identifying the Components of the Mixing Nozzle

There Are Four Components to the Anti- X- Over Nozzle Design

1. Stamped Plastic Film Check Valve
2. Plastic Moulded Back Cap
3. Plastic Moulded Clear Front Tube
4. Plastic Moulded Mixing Element

Once the back-flow prevention design accomplished by the film check valve was validated, it was necessary to establish a process and supplier to produce the film check valves. Having completed this design, I needed to address the design for assembly and manufacturing of the remaining components. These four pieces are designed to align, capture, seal and snap together in a simple assembly process.

Case History 2 – Anti-X-Over Mixing Nozzle

2.7.6 The Plastic Film Check Valve Design

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 2-12: Drawing of Film Flapper Valve Design Taken From Brown Patent

Highlights of the Film Check Valve Mixing Nozzle Backflow Prevention Design:

- Made of a film that can easily flex and seal but return to flat for closing
- Hole in the centre (331) allows for easier location during assembly
- Hole in the centre (331) allows for entrapment of valve for assembly
- Adhesive applied to valve (328) allows for sticking the valve into the back cap
- Cross shape allows for easy rotational positioning during assembly
- Cross shape provides more surface area for adhesive contact
- Area of no adhesive (312) is to allow for flap to open and closet

Case History 2 – Anti-X-Over Mixing Nozzle

2.7.7 The Nozzle Back Cap Design:

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 2-13: Drawing of Nozzle Back Cap Redesign Taken From Brown Patent

Highlights of the Back Cap Mixing Backflow Prevention Design:

- Made of a glass-filled polypropylene for strength and flexibility
- Boss in the centre (330) allows for location of valve during assembly
- Surfaces designed for increased area for location and adhesion (326 & 328)
- Cross shape allows for easy rotational positioning during assembly
- Tapered walls (310) allow easier finding and positioning during assembly
- Area of no adhesive (312) is to allow for flap to open and close

Case History 2 – Anti-X-Over Mixing Nozzle

2.7.8 Front Mixing Tube Design

The front tube functions to hold the mixing element and materials during mixing, and it functions to determine the spray or pour pattern of the application. The shape of the spray tip determines the pattern and a number of different spray tips that have evolved over the years. For the purpose of the project, it was a goal to not change these spray patterns, as customers in their respective applications have established the performance expectations and benchmarks through years of use. Making a spray pattern change would actually disrupt the established pattern benchmark and user expectation long established in the marketplace.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Case History 2 – Anti-X-Over Mixing Nozzle

<http://www.abbuildingproducts.co.uk/images/content/productimages/12057637080.jpg>

The front mixing tube did require change to accommodate the new snap fit manufacturing method. In addition, the original nozzle does not have any accommodations for assisting the user in snapping the nozzle into the dispenser body. This required some force as the barbs on the nozzle inlets would deform to seal as the nozzle was inserted. Thus to facilitate the nozzle insertion I expanded the cavities I designed for the snap fit to become wings that provide an affordance for the users to put their fingers in place to easily insert the mixing nozzle into the dispenser.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 2-15: Nozzle Front Tube Images Adapted From Brown Patent Drawings

Eliminating the sonic welding of the previous manufacturing process was a key productivity enhancer for the redesign. By designing a male set of two barb projections on the back cap allowed for easy moulding. Designing the female pockets into the mixing nozzle front tube and integrated the structure for the insertion pads also allowed for easy moulding in both cases. The mould did not require any expensive side actions or inserts and allowed for straightforward multi-cavity moulded parts that did not require any post-processing before assembly.

An important point here is that while quite often a designer may not possess the experience or specialty knowledge of a process to optimise these designs on their own, they must rely on their design research and interaction with the suppliers and their engineers that possess this disciplinary knowledge. While not all suppliers are willing to stray off into new or unproven territory in their work, many are willing to work with you. In my experience, it is precisely these supply relationships I needed to establish when I was seeking to pioneer new knowledge solutions and lacked the specialist knowledge. While many suppliers are focused on operational efficiencies to provide the lowest cost, that is a good strategy for a commodity business. I have found

Case History 2 – Anti-X-Over Mixing Nozzle

that working together as a team can often pioneer the new knowledge solutions, and achieve the Lean Design cost and quality objectives at the same time. These relationships are built on mutual trust and respect.

2.7.9 Mixing Element Design

For the purpose of this project, the component mixing element was kept the same, as the mixing aspect of the current dispenser was not an issue. In fact, there was a long history of experience with this original mixing element and the formulation of the various polyurethane foam variations that utilised the dispenser were purposely optimised to the existing mixing and dispensing nozzle parameters. Thus, a constraint for the redesign was to not change those existing mixing nozzle parameter so as not to affect the established formulation performance interaction between the formulated components and the mixing aspect of creating the polyurethane foam.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 2-16: Patent Images Updated From Brooks and Brown Patents

Although accommodate the new anti-crossover functionality of the nozzle the redesigned mixer to have a tail piece added to it, this tail piece was designed to capture the film check valve during assembly of the new anti-crossover mixing nozzle.

Case History 2 – Anti-X-Over Mixing Nozzle

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 2-17: Brown Patent Image With Mixer Tail Piece Highlighted in Black

2.7.10 Integration of the Components Design

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 2-18: Anti Crossover Nozzle – Image Taken From Dow Chemical Website and Annotated

The four nozzle pieces were designed to integrate into a simple-to-assemble, low-cost and highly reliable anti crossover nozzle assembly. The design of this product worked in a combined interaction with the redesigned Insta-Flo dispenser of Case 1 to eliminate the possibility of unintentional or intentional crossover due to material backflow from the mixing nozzle into the dispenser as previously discussed.

The success of this integration is at the heart of a process called Design for Assembly and Design for Manufacturing. In the Design for Assembly process the designer must not only focus on the form and functional requirements of the components, but also how these components will be produced, transported, stored, handled, presented at the assembly line, identified and engaged for assembly and

Case History 2 – Anti-X-Over Mixing Nozzle

the interaction of the component with the other components in the production process. Designing for assembly requires that the tolerances, shape, ease of assembly and other manufacturing considerations be incorporated into the new product design process. A robust design for manufacturing effort will seamlessly integrate into a lean design for manufacturing process. This integrated design for assembly and manufacturing is critical to the new product process as an early stage consideration and a continued focus throughout the design process. The goal is to design the assembly right the first time, and not to have to go back and redesign the components when they fail to perform in production or in the marketplace.

2.8 Design Solution as Described by Brown Patent US 6,021,961

Accordingly, it is an object of the present invention to provide an improved mixing and dispensing nozzle for urethane foam or similar multi-component systems.

Another object of the invention is to provide mixing and dispensing nozzle components which can be assembled by the simple process of snapping one component inside the other, thereby trapping the third component in the dispenser, with the anti-crossover valves being secured in place.

Yet another object of the invention is to provide a mixing and dispensing nozzle which contains an internal set of valve leaflets normally serving to close off the rearward flow of material into the dispenser or gun.

Still another object of the invention is to provide a combination of a multi-piece nozzle which can be easily assembled, together with leaflet style valves restricting crossover contamination in the use of the apparatus.

A further object of the invention is to provide a multi-piece nozzle which includes a baffle mixing element having vanes disposed around a central backbone and having the backbone engage the rear wall of one of the components of the valve as an aid to assembly.

A still further object of the invention is to provide a valve for each of plural inlets and having a single leaflet, made from a thin sheet of plastic film such as a polypropylene, a polyester or the like.

An additional object of the invention is to provide a single valve assembly comprising a pair of leaflets disposed to either side of a thermally welded or mechanically or adhesively affixed portion which attaches the centre portion of the leaflet to the rear wall of the nozzle.

Case History 2 – Anti-X-Over Mixing Nozzle

Another object of the invention is to provide a nozzle that snaps together and includes wings or finger-gripping handles on the body of the nozzle. A still further object is to provide a snap-together construction which includes a moulded-in rib or gasket between the sections to insure a tight fit.

The invention achieves its objects and advantages in two ways. The first is to provide a telescoping, snap action type assembly for mixing and dispensing nozzles, with optional wings or finger-gripping portions, and the other is to provide a valve, preferably in the form of leaflets, for two or more inlet openings, with the valve leaflets extending over the opening and closing them off by their own innate resiliency, and remain forcibly closed by the internal pressure within the mixing nozzle. At the same time, ready opening occurs under the force of incoming liquid components, with the valve leaflets being preferably affixed to the rear wall of the nozzle by thermal attachment, by an adhesive, or mechanical entrapment (Brown 2000: col. 3–4; bullet points inserted for clarity).

Case History 2 – Anti-X-Over Mixing Nozzle

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 2-19 Patent Images of the Brown 961' Solution

2.9 **Reflection on the Differentiation by Design Process**

The initial purpose of this project was to take advantage of the window of opportunity created by the need to build new tooling for the production of mixing

Case History 2 – Anti-X-Over Mixing Nozzle

nozzles for the existing Froth Pak business. The existing tooling had produced millions of mixing nozzles of the original Brooks style, and had simply worn out, creating production down time and quality issues with the components. Seizing this opportunity as an outside consultant with deep knowledge of the product line, I proposed that a redesign be initiated to focus on two main areas:

My area of need that I was aware of was to reduce the production cost of the mixing nozzles by integrating the latest technology of plastics and eliminating the need to sonic weld the nozzle bodies. The sonic welding was unreliable and very labour-intensive to confirm that a weld and seal actually did take place in production.

The second area of need and for the most part needs that that were not readily apparent was to create a mixing nozzle design that eliminated backflow of material from the mixing nozzle into the dispenser. As the Insta-Flo dispenser had virtually eliminated this once common problem almost 10 years earlier, the problem was not considered. This process was built on identifying the root cause of the problem as Brooks had done in 1978, and successfully creating a solution that could work.

Having the opportunity to redesign I researched the other stakeholder needs beyond the ones identified above to seek insights into other opportunities to design new value into the new nozzle. I identified these other unarticulated needs that I was able to include into the redesign that have contributed into the competitive advantage of the new Anti-X-Over Mixing Nozzle product

1. Need to provide an easier way to engage the nozzle on insertion
2. Need to create clear nozzle front tubes, but allow for colour coding

Primarily this project was very much a Design for Assembly and a Design for Manufacturing project, once the anti-crossover design was perfected. The project is an example on how design can strategically integrate the needs of many stakeholders at the same time in the design process as the design evolves. This is only possible if the designer strategically seeks these needs early on in the process.

2.10 Reflection on the Business Solution

The development of the Insta-Flo Anti-X Over nozzle that resulted in the Brown 961' patent had several direct impacts on Insta-Foam Products business. The

Case History 2 – Anti-X-Over Mixing Nozzle

dispenser was designed, tested and brought to market in less than a year and had an immediate impact on the business.

- First the nozzle redesign immediately reduced the cost of each nozzle by more than 100%, the actual numbers are protected by a confidentiality agreement. This cost reduction directly resulted from the design for assembly and manufacturing integration into the design process. This reduction was significant when considering the added costs of creating the anti-crossover feature into the new mixing nozzle.
- Customer complaints about the mixing nozzle decreased immediately, the issues with nozzle quality and leakage due to sonic welding manufacturing issues disappeared.
- The ability for users to easily see if there is a used and blocked nozzle in the dispensers is readily apparent, thus reducing the inadvertent unintentional activation of the dispenser with a clogged nozzle.
- The new nozzle was much easier to grip and install into the dispenser as the affordances of the wings and the mapping of their shape resonated with users.
- The use of the dispenser by novice users expanded greatly, a valuable product only used once by trained professionals because of the difficulty of use has evolved into a product that can be purchased today at all the major Home Centre stores to be used by consumers.
- The choice of materials allowed for a robust colour-coding scheme that combined solid back cap colours with transparent tinted front tubes to allow for the easy identification of the many nozzle variations used in the marketplace.

Case History 2 – Anti-X-Over Mixing Nozzle

Product Data Sheet From Dow Chemical Page

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 2-20: Product Data Sheet for the Anti- X- Over Nozzle, page 1 (Dow Chemical)

Case History 2 – Anti-X-Over Mixing Nozzle

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 2-21: Product Data Sheet for the Anti- X- Over Nozzle, page 1 (Dow Chemical)

Case History 2 – Anti-X-Over Mixing Nozzle

2.11 Conclusion

Upon reflection, I am confident that my customer would have been very happy with my performance on this project if I had completed all of the tasks without addressing the intentional nozzle back-flow condition still possible after the dispenser redesign completed 10 years earlier. For me it was my desire to pursue where Brooks had left off some 20 years earlier with his attempt at stopping mixing nozzle back-flow that would distinguish this project and thus my personal differentiation as a Consultant. Why I chose to push the design envelope when the opportunity presented itself beyond what the customer expected can only be explained by my philosophy of design driving my design process. Although not a readily apparent need, I was able to see that this need was important for the future growth of the product line, I believe that the nozzle backflow prevention of the anti-crossover design was critical for the simplification of the kit usage by inexperienced users. While there is no way to judge that this is or is not the case, I will offer this evidence to support my position.

When I started on this journey with this product line in 1985, the product was successful but only with specially-trained operators working for contractors or in-house specialists of large organisations trained to manage the difficulties of the original pioneering Brooks dispenser, which at the time was a breakthrough. The Insta-Flow redesign did eliminate the majority of the dispenser performance issues as outlined in Case 1 and the use of the Froth Pak kits grew as more and more distributors and contractors became comfortable with the new performance benchmarks. Although the Froth Pak kit market was still primarily a professional user group with little or no consumer level users of the product. Today, now 20 years after the anti-crossover nozzle was introduced and combined with other dispenser and kit improvements, these two component kits that were once only used by highly-trained applicators are now sold in the consumer building product retailers. Any consumer in the US needing PU Foam for insulation or other applications can purchase a kit at a local store or even online and use that kit without issues because of the robustness of the dispenser and kit design.

In this case, the design process has affected a number of areas of the product experience beyond the traditional form and function. It has added value in the supply chain, the distribution channel and the business model. In addition, the intellectual

Case History 2 – Anti-X-Over Mixing Nozzle

property created served to protect the business's investment in technology development, as well as contribute to the intangible value of the business. When I first started this technology was owned by a company named Insta-Foam Products, within a year of my arrival it was sold to Flexible Products Company for just over ten million dollars and 15 years later the whole Flexible Products business was sold to Dow Chemical for hundreds of millions of dollars. Flexible Products had a lot of technology and business developed from that technology. Of the intellectual property, much of the technology patented were my patents, many beyond those of these case studies. I am confident that Flexible Products as a company was able to invest and reap the rewards of that investment based on a commitment to a design and development process that kept them at the forefront of the marketplace.

Case History 3 - The Bionic Wrench

3. Case History 3 – The Bionic Wrench Design and Development

3.1 History of the Case

3.1.1 Seeking a Case History of the Differentiation by Design Process

The creation of the Bionic Wrench evolved from a desire to create a case history for the Differentiation by Design process. This need arose from my experience in selling design services to clients. As an independent new product design and development consultant, you are not only required to practise the design process for your clients, you must constantly be seeking new project opportunities to fill the design business pipeline.

As my design business arose from a successful career working in industry first as an engineer, plant manager, project manager, business unit leader, vice president and ultimately an entrepreneurial design evolving into a designer consultant. I had tacitly created a design process, building on the experiences of my past work that I relied upon to deliver the new product value and competitive advantages that my clients sought, while at the same time doing it strategically so that I was also getting patents to protect the clients' new product investment. The focus of my design evolved over time, with a strategic orientation for seeking new product viability through my design.

One challenge that I encountered when selling my design and consulting services for new product development was the challenge of expanding my clientele beyond those clients that were very familiar with my services. Existing client relationships were easy, and new business could arise out of a lunch conversation. I had established a successful history with these clients, built on a basis of trust and respect, and of course, I delivered the new product competitive advantages in the marketplace that they sought, and came to rely on. Many times creating intellectual property in the form of patents and trade secrets that became valuable intangible company assets.

In those instances, where I was selling my services to prospects that did not have past experience with my work, or had not competed with products I had

Case History 3 - The Bionic Wrench

designed, the selling process was much more challenging. I needed to convince them that an outside person could deliver the new product results they were seeking with a certainty of success and in a form that would be valuable to them. As I had considerable success in my previous work, the evidence was there, although I had to sign a confidentiality agreement with my clients that often stipulated that I could not disclose the nature or activities of my consulting relationship with them. I found it very difficult to discuss the details of my design successes with others beyond showing them the stack of patents that were in the public domain with my name on them. Especially the details of how the products evolved, thus I could not ethically or legally discuss at any level of specificity.

This frustrated me, there were a number of products on the market that I had designed, developed and patented as a consultant but they were not recognised as my designs, even when they received awards, the awards went to my clients. Although my clients paid me well and did at times recognize me with internal awards from their organisations, my recognition as a designer, as well as my ability to grow my design business based on my work was inhibited. Thus I had a desire to create a new product completely designed and funded on my own – from concept to commercialisation – that would serve as a case history for my Differentiation by Design process, and if successful, be attributable to my design and invention abilities.

While I had this goal in the back of my mind for several years, what quickened me into taking action on it was actually a tragic event. I was in Las Vegas for a packaging industry trade show on the week of Sept. 10th, 2001. Industry events were places to meet with vendors, do research, interact with other professionals and meet new clients. I was doing all of that, and I had secured a meeting with a past client to discuss a new product advancement for his business that I envisioned. We met and he was interested, we decided to meet again the next day Tuesday to formalise the project.

The next morning was Sept. 11th, 2001, the day the World Trade Centre in Manhattan was attacked. Our meeting that day cancelled and the further discussion postponed. My prospect, as well as many other people rented cars and decided to drive back to their homes. I ended up staying in Las Vegas for the whole week waiting for the planes to start flying again. It was during the long days of this week that I decided that I really needed to pursue that in-house new product design opportunity.

Case History 3 - The Bionic Wrench

So once I returned home, I started putting some serious effort into identifying a real problem to solve that had the commercial potential for both a technical and business start-up success.

Experience had taught me that it is much easier to begin a process like this with a real world problem that is in dire need of a solution. Opportunities with market viability built into them are critical for success. Far too often, a design is pursued as a solution looking for a problem, building a commercial enterprise from this strategy is like pushing a rope up a hill. Therefore the problem finding of real world problems with market-driven needs, searching for a solution often have customers willing to pay for the a better solution. There are the projects on the other end of the spectrum also, tremendous market viability when solved, but so challenging they are seemingly impossible for any number of reasons. The right project has baked in market viability and a technical white space possibilities for execution and productisation.

3.1.2 Seeking the Right Problem to Solve

In the 2001 – 02-time period I was actively searching for a case history project to demonstrate the Differentiation by Design process for my product design and development consultancy that I started in 1991. Upon reflection, I can say that I was overwhelmed by the search for a real problem-case to use. Identifying a problem that had the commercial viability, with real potential to evolve into a business. In all of my past projects, the problem, or I should say the symptoms of the problems were evident. Many of my past projects were exactly these type of projects as seen in Cases 1 and 2, one thing I quickly realised was; finding a commercially viable problem with sufficient market potential was a very challenging task in itself. Seeking this real problem consumed me for months; I now see this same frustration in teaching when students seek out real problems for a meaningful class project. We often complain about our problems we have to deal with, but the one good thing about a real problem to solve is that it brings focus to your work.

The eventual project did not come easily; although I was busy with other client work, I was actively engaged in seeking and mentally screening opportunities for this in-house project. It was not until the following spring; almost nine months after my Las Vegas trip did I stumble upon a potential opportunity. Interestingly, there is a saying that “Luck is what happens when preparation meets opportunity”, I believe that this

Case History 3 - The Bionic Wrench

was the case here. While searching for the right opportunity, I was mentally modelling the many ideas that I came across, not for the functional attributes of the opportunity, but for the unmet market needs and commercially viable business models.

My focus for the case was to search and evaluate possibilities with the Levitt 1/4-inch hole framing. Questioning what are the stakeholder needs to create a viable product and business to serve as a case history of my design process. I am not sure I can articulate a sure fire way of accomplishing this aspect of the new product development process, but I do know is that you have to find a real problem, and customers who are willing to pay to solve that problem. No effort and investment in the world can create a commercially sustainable product that does not have customers willing to pay for the benefits the product provides.

- Seeking a Design Case history Needs:
- Sell the consulting services of Differentiation by Design
- Based on novel value creation that was protectable
- Differentiated competitive advantages
- Sustainable and viable business strategies
- Did not rely on patents alone for the case lessons
- Tangible product that everyone understands the problem – solution
- Communicates Wow design experience
- Problem Framing & Finding – Form & Function

3.1.3 Luck Strikes the Prepared Mind

Serendipity or perseverance based luck struck in the spring of 2002. At my home I have many oak trees that drop leaves in the fall each year, if you do not get these leaves up they will kill the grass under them in the spring. To do battle with all these leaves I have a riding lawn mower. There is a grass cutting arrangement of the mower deck for summers and a leaf mulching arrangement for fall. Changing the mower deck from grass cutting to leaf mulching requires adding and removing these baffles and attachments to accommodate the leaf collection rig. My son was in high school and part of our spring routine was to convert the fall mulching configuration back to the spring grass-cutting configuration for summer. It was spring and I had assigned my son the task of converting over the lawn mower deck from last season's mulching and cutting the lawn before he headed out for the day.

Case History 3 - The Bionic Wrench

That day I was working in my home office, when my son came into the room and starting rooting through my work tool chest, I have a very well-equipped tool chest that I had built up over the years to support all of the mechanical design work I had done. I watched as he grabbed a plier-type tool called a Robo-Grip and headed towards the office door. Straightaway I recognised that he was intending to use this pliers type tool on the fasteners of the lawn mower deck, and I immediately told him not to use the pliers on the nuts and bolts of the deck because he would most likely start stripping the corners of the bolts. We all have encountered those fasteners that had been previously rounded by the same process my son was planning.

He was in a hurry, he wanted to get the task completed and he did not want to spend the time sorting out what corrects size wrenches or sockets he needed to convert the mower deck. Defensively he countered my argument with his own saying that he needed a tool that could grip the nuts as they were already worn and covered with the dirt of being in use over the years, he further insisted that the pliers were the best choice because of the condition of the fasteners. We obviously did not agree but he went on his way, and I went back to work. It did not occur to me immediately, but after a few weeks when I was again thinking about a proper case, I realised that this was a situation where a user was expressing their needs in a real world fashion.

What I realised was that my son was partially right, and the problem was right in front of me. He wanted a tool that adjusted and gripped like a pliers, and I wanted a tool that performed like a wrench used on the mower deck fasteners. I was a bit of a “toolaholic” and I could not think of anything that existed to serve this need currently in the market beyond plier type tools. I started researching the problem.

3.1.4 History as Described and Cited by Brown Patent 6,889,579

This invention pertains to a hand tool and more particularly, to an adjustable gripping tool which, as a result of manual operation, self-energizes, automatically configures to engage differently dimensioned and shaped workpieces and de-energizes upon release of actuating force.

Various types of adjustable gripping tools are known in the art. Specifically, several known adjustable gripping tools are embodied in the form of a “crescent” wrench, an adjustable socket wrench, pipe wrench, vice grips, crimpers, bolt and nut cutters, pipe and tube cutters, and various other “plier-type” gripping tools.

Case History 3 - The Bionic Wrench

A crescent wrench is an adjustable open-ended wrench that has stationary rotatable screw which engages a toothed rack formed on a first jaw element movable with respect to the second jaw element extending from the first element.

The adjustable socket wrench includes a shell housing movable elements, such that movement of the first element with respect to the shell causes the elements to move with respect to the shell in order to engage the workpiece.

One cutting tool version has adjustable cutting jaws that when tightened and rotated around a tube score and cut the tube. Another version of the cutting tool uses a blade-cutting mechanism.

The plier-type devices include a pair of first elements connected in such a manner so as to move at least two jaws toward one another in order to engage the workpiece.

3.2 Research Benchmarking of the Existing Solutions

The functional design will be discussed in detail later, but I needed a commercial benchmark so that I would be able to research the emotional and economic drivers of the business opportunity. For commercial viability it is essential that you understand the existing business playing field and rules of the game in order for you to judge the viability of the market space as well as establish the behavioural, performance, and economic drivers of success and failure in the market space you intend to compete.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-1: Images of the Robo-Grip (images obtained through Internet search)

For my commercial benchmark product I chose an innovative pair of adjustable pliers named the Robo-Grip (see Figure 3.1). I chose this benchmark because it had achieved considerable market success as an American-made product during the 1990's. Beyond the shared market the Robo-Grip eventually proved a very good benchmarking choice, which will be discussed later, but the list below are some highlights of the shared benchmarks.

Case History 3 - The Bionic Wrench

- Domestic American-made product
- Innovative adjustable pliers built on a patented mechanism
- Plate manufactured by stampings for body components
- Similar type of problem style, but for the pipe and fitting application
- Similar type of user – purchaser profile
- Similar distribution channel profile

Sears was the exclusive retailer for the Robo-Grip in the 1990's and it was so successful that there were news articles written about it as a major contributor to Sears's earnings. The inventor was a man named William Warheit who sold the rights to his dentist, a man named Hal Wrigley, in the early 1980's. Hal worked for 10 years trying to get the product to market, and finally hit the right combination of attention-getting and merchandising to allow the product to take off. I do not have the exact numbers but it has been guestimated that the Robo-Grip sold over 30 million units during its lifespan.

In 1996 the Chicago Tribune reported:

A self-adjusting pliers developed by a retired engineer and a dentist in Pennsylvania turned out to be the hottest item at Sears, Roebuck and Co. this past holiday season.

[“We didn’t have Tickle Me Elmo, thank goodness, but we did have Robo-Grip,” says Sears Chairman Arthur C. Martinez, referring to the hand tool.](#)

[Sears was the exclusive seller of what it calls the Craftsman Professional Robo-Grip Pliers at a time when other retailers quickly ran out of the scarce Elmo dolls. \(Sears stores don't have toy departments.\)](#)

[Martinez says Sears sold 2.5 million pairs of Robo-Grip Pliers between Thanksgiving and Christmas, or at a rate of 50 per minute. The spring-loaded pliers, which can be operated with one hand, come in three designs – a 7-inch curved jaw configuration at \\$19.99, a 9-inch straight jaw and 9-inch V-notch jaw at \\$24.99 apiece. A gift set of all three sold for \\$49.99.](#)

According to Sears, Warheit became frustrated in 1982 while helping his son Matthew put a new transmission into a car in their garage in Zelienople, PA. Struggling to adjust a conventional pliers by hand, Warheit got the idea for a self-adjustable tool. His dentist, Hal Wrigley, spent the next six years working with Warheit to perfect the gadget. To obtain capital to produce the new tool, they sold their small company to

Case History 3 - The Bionic Wrench

Emerson Electric Co. in St. Louis. Sears introduced a first version of the Robo-Grip in the spring of 1993 (Gruber 1997).

3.3 Description of the Problem from the Brown US 6,889,579 Patent Record

This invention pertains to a hand tool and more particularly, to an adjustable gripping tool which, as a result of manual operation, self-energizes, automatically configures to engage differently dimensioned and shaped workpieces and de-energizes upon release of actuating force.

Various types of adjustable gripping tools are known in the art. Specifically, several known adjustable gripping tools are embodied in the form of a “crescent” wrench, an adjustable socket wrench, pipe wrench, vice grips, crimpers, bolt and nut cutters, pipe and tube cutters, and various other “plier-type” gripping tools. A crescent wrench is an adjustable open end wrench that has stationary rotatable screw which engages a toothed rack formed on a first jaw element movable with respect to the second jaw element extending from the first element. The adjustable socket wrench includes a shell housing movable elements, such that movement of the first element with respect to the shell causes the elements to move with respect to the shell in order to engage the workpiece. One cutting tool version has adjustable cutting jaws that when tightened and rotated around a tube score and cut the tube. Another version of the cutting tool uses a blade cutting mechanism. The plier-type devices include a pair of first elements connected in such a manner so as to move at least two jaws toward one another in order to engage the workpiece. The crimping tools provide various functions, such as specialty segmented dies that expand or contract via interaction of a tapered boy with a fixed diameter or a plier-type device crimper with jaws that have been modified as a special head to crimp the workpiece.

Each of the prior art devices have disadvantages. The crescent wrench is not automatically resizable during use. The socket device is limited in its effective range of dimensional capability. In other words, a large number of sockets is needed to service a relatively standard range of workpieces, the workpieces must have a standard configuration and the workpieces must be engaged axially.

The plier-type devices fail to engage the workpiece evenly around or within the circumference with proper offsetting forces and stability which aides in operation of the tool. The plier-type devices also concentrate the applied mechanical forces in a point-loading configuration creating pressure points and stress risers on the workpiece surface.

The tube cutting devices cannot be used with one hand. Another disadvantage of tube cutting devices, in particular, knife blade cutters, is that the tubing is often distorted as a result of the asymmetrical cutting forces applied by the blade against the tube. Other

Case History 3 - The Bionic Wrench

tube cutting devices, such as screw-and-wheel-type tube cutters require continuous rotation of the cutting wheel around the circumference of the tube while simultaneously increasing the force applied by the cutting wheel to the tube in order to increase the cutting depth.

Prior art crimping devices cannot create symmetrically balanced crimps with a simple hand tool. For example, crimping a metal sleeve on a hydraulic hose requires a press and a proper die for proper application. Also all of the previously available gripping tools either loosely hold the workpiece or hold the workpiece in a manner that concentrates and focuses the gripping forces in a point pressure-loading configuration. This concentration of gripping forces is on certain points concentrates the force and serves to oftentimes deform the workpiece. Also the previously available tools for wrench applications could not be easily sized to the workpiece.

Therefore, there exists a need in the prior art for an adjustable gripping tool which, as a result of manual operation, self-energizes the tool action, may be automatically sized and resized to engage a workpiece, de-energizes upon release of actuation force, that has a broad range of dimensional capability, engages workpieces axially and radially and provides offsetting forces for stability in operation. Beyond the ability to resize the gripping range, the gripping tool of the present invention symmetrically translates the force applied to the gripping tool onto the workpiece in a symmetrically balanced and mechanically advantaged and efficient way. Thus, an even distribution of gripping and rotational force about the workpiece is achieved; whereby allowing for the most efficient distribution of mechanical stress about the workpiece. For any given force required to manipulate the workpiece the present invention will accomplish the work with the minimal distortion of the workpiece by distributing the work force over the largest area of the workpiece. Other advantages of the adjustable gripping tool of the present invention include decreased costs, increased productivity and multi-access engagement of the workpiece resulting in a mechanically advantaged, efficient, even and balanced distribution of working forces.

3.3.1 The Knowledge Gap

How can you design a hand tool that functions like a pliers but performs like a wrench? Is it possible to design a novel and inventive solution that can be domestically produced at a price that customer would be willing to pay. Is there a white space in this commercial business playing field where a competitively advantaged solution to the problem can compete and sustain a business?

Case History 3 - The Bionic Wrench

3.4 Reflection on the Problem

Often when approaching problems like this from a functional perspective, designers seek to improve the existing products, in the hand tool area there are countless improvement patents to the Crescent adjustable wrench, many addressing this same problem of actively engaging the faster while applying the rotational forces. The traditional framing of a parallel jaw type wrench to address the problem would take me down a path of creating a gripping type parallel jaw wrench. I would characterize this as the Levitt 1/4-inch drill focus. There are countless versions of this type of tool in the market and limitless choice of this style of wrench would make the productisation very challenging. Even a great technical design would have very little commercial viability, my framing of the problem-solution needed the 1/4-inch hole perspective of Levitt.

Seeking a benchmark product would have been a challenge if I was first thinking about the 1/4-inch drill as my frame of reference, as I was in a new functional space that by nature lacks similar functional benchmarks, it is hard to find a framing reference for something that has not been developed. But when you focus on the 1/4-inch hole reference framing for benchmarking, you will be able to bring a new perspective to the real problem you are addressing in your benchmark search. As stated previously, the framing and the research direction that framing provides is as important as the design process in new product development. Proper framing brings focus and provides non-traditional opportunities for development milestones as you move through the design and development process.

The functional design arose by first benchmarking and identifying the existing solution knowledge in the marketplace. This process relies on getting into the marketplace and working with users to see what products are being used and why. During the development of the Bionic Wrench in the 2003-2004 era of the Internet, word searches were available. This was primarily the sole practise beyond personal marketplace experience. In today's world, designers have internet access to records that are quickly searchable; this facilitates the benchmarking research process in a number of ways. Boolean word searching of the problem, solution and attributes of existing solutions can lead the researcher to existing solutions. In addition, using

Case History 3 - The Bionic Wrench

similar Boolean word searching, one can search the images associated with the search results

My mental modelling and ideating were focusing as I continued my immersion into the functional aspects of the problem. I envisioned collet-like engagement as was used in machine tools and work holding devices. As I modelled a wrench head to emulate the action of one of these types of work holders, the complexity of the mechanism became like a watch. I knew from experience that I needed a very simple and robust mechanism, which was adaptable to a thinner profile wrench head versus the typical collet designs. Although I wanted the collet-like radial converging and diverging action that could engage all six flats of the fasteners, I began to mentally model the iris type motion of circumferentially opening and closing.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-2: Images From Patents and Internet Searches

I do not know exactly when but I had a mental image of a mechanism that I had experienced when I was younger. That was the experience I had when looking into a lens of a SLR camera, I remembered cocking or advancing the film lever and pushing the picture-taking button and watching the shutter open and close in that iris-like motion. I recall being fascinated by this mechanism, to the point I also remember my father admonishing me for continuing to dry fire the camera, pointing out that I was eventually going to break it.

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-3: Images From Internet Search of Camera Shutter

The mental modelling of this mechanism focused my ideation on this design and I began investigating the existing mechanisms for these aperture changing shutter-type devices. What I learned was that while the shutter mechanism was great for cameras it was not readily adaptable for engaging the flats of a fastener. The mechanism needed the radial adjustment but it also needed to perform like a wrench. However, the motion of opening and closing was an inspiration. I continued to mentally model and search for other mechanisms and I started working on a cam-like mechanism that would drive the jaws inward but they required lifting springs on each jaw for the return movement. I continued to search for a solution, one day it occurred to me that if I used a slot instead of a cam I could both drive and raise the jaws symmetrically utilising one plate with multiple slots and one spring for all jaws, and this is what inspired me to the current design. With this idea, I began creating sketches and drawings to develop the idea and see if I could make it operable.

My mechanical design process was CAD-based, I had started with CAD when it appeared in the marketplace in the early 1990's, the first systems were very basic, creating 2D sketches, used mostly for draftsman converting from hand drawing to CAD drawing for creating engineering documents. However, as the software and technology evolved, the CAD systems evolved from 2D drawings to 3D virtual models. By the early 2000's I was designing 3D CAD modelling directly on the computer. Using any software, the design and revisions for mechanical design were much more efficient and easier to virtually model on computer.

My first research focused on the existing marketplace, were there any products in existence that gripped like a set of pliers and performed like a wrench? The obvious solutions were apparent, most notably the very successful Vice Grip pliers. I was well

Case History 3 - The Bionic Wrench

aware of this amazing tool, and I had used it many times. However, while the Vice Grip does have a very strong gripping force, with its leveraged locking mechanism, it can create damage to the fastener. From my experience, the forces that were created were point loaded primarily in two points on the fastener, and while this tool has had almost un-paralleled success, the stress concentration of the plier's type tools can readily deform the fastener.

Another category of adjustable wrenches was the very familiar Crescent style adjustable wrench. This tool has also dominated the adjustable wrench marketplace. I had used this tool many times. The Crescent wrenches work very well although they are not easy to adjust when they get older, and often the parallel jaws do not grip the fasteners. Sockets and standard one-size wrenches are pre-sized to work on standard fastener sizes, and this is a very common method for mechanics and professionals who often have substantial tool chests in close proximity to their work. I have found it often difficult to judge the fastener size by simply looking at it. This is complicated by the proliferation of fasters in both SAE and Metric sizes intermixed in the products you would find around the house.

The fasteners themselves also provided a challenge, as they were made of varying qualities of metals, and to different degrees of dimensional accuracy. The accuracy range complicates the problem for pre-sized wrench and socket makers, as they have to size their tools to the high side of the lowest fastener tolerance to allow for use on these fasteners. When a pre-sized wrench or socket is placed on a fastener that is on the lower tolerance side, there is a loose fit and this creates a point loading situation. We created the images below to articulate this problem to users (see Figure 3-4).

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-4: Images From www.rainydaymagazine.com internet posting

Case History 3 - The Bionic Wrench

3.5 Reflection on the Needs

My first instinct when I am challenged by a new opportunity as described in this case is to frame the problem statement. For me this was a new tool that adjusted like a pliers but performed like a wrench, specifically targeted at not damaging the nut or the bolt heads. “Can I design a tool that grips like a pliers, on the fastener flats, but performs like a wrench?”

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-5: author's research into existing multipurpose tools (images from the Internet)

After researching what products were available on the market, I studied them to see what attributes worked and what did not work. I then studied how people used the wrenches in practise; also personally having had a significant amount of experience in tool use, I relied on my personal experiences. For a long period of time while I had mentally modelled improvements to existing tools but I was not really getting anywhere. I have found this to be a very common part of the design process from my past practise that quite often the design process involves iterations through this mental modelling of alternatives on the pathway to a new solution. Almost a necessary mental immersion into the world of the problem, I think this hyper-focused state over a long period of time mentally debating the pros and cons of various ideas with the many variables is sense-making of the problem for the designer. I find that when I am in this immersive state that I will dream about the problem at night.

Case History 3 - The Bionic Wrench

3.5.1 Performance Needs:

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Case History 3 - The Bionic Wrench

Upon benchmarking the existing functional solutions, and the needs of the various stakeholders I analysed the opportunity from the perspective of where and how can I differentiate this new product experience in a novel and competitively advantaged way?

1. How could I engage on the flats not the corners maximising the force distribution, and reduce or eliminate point-loading failure?
2. How could I actively engage in a grip like pliers fashion, providing secure engagement, as seen in pliers-type tools?
3. How could I have simple adjustability like pliers that covered a wide range of sizes?
4. Can I create a design that could be manufactured domestically at a price customers would be willing to pay?

3.5.2 Need Finding Beyond Form and Functional Performance

Beyond the functional needs associated with the use, I knew from experience and practise that I had to also look beyond form and function for those needs that are just as important for the design requirements for a successful and viable commercial product. When designing in these areas, it is important to choose a benchmark product whenever possible to give you a roadmap of a similar effort or efforts to commercializing your new product.

Other Design Areas of Focus Needed for Successful Commercialisation:

- Finding a Benchmark Product
- Product Platform Design
- Mass Customisation Design
- Line Extension Design
- Product Identity Design
- Supply Chain Management Design
- Distribution Channel Design
- Business Model Design

3.5.3 Form Need Finding – Form Following Function

While designing in the areas of Form and Function have always been the domain of design, it has been my business experience that in today's competitive marketplaces the designer must venture into all potential value-creating aspects of the product experience to seek and create new value on the road to establishing a complete commercially viable product. Part of the Differentiation by Design case

Case History 3 - The Bionic Wrench

history objective was to identify a product to bring focus to those design opportunities beyond the form and function and the heuristics to research and establish unique needs.

I will address each of these areas to comment how I incorporated this strategy into the Bionic Wrench development. Beyond getting to the root cause of the problem discussed earlier, there were a number of areas to research in the Supply Chain, Distribution Channel and Business Model that strategically integrate into a robust and viable new product design and development process. It was these insights that evolved out of my practise, and how it became clear for me that they were design-based activities that the whole business was relying on.

The following table highlights many of these areas, but the reality is that the opportunity to create value throughout the consumption chain is as endless as the potential for new products, thus there is no process roadmap or path to a truly unique new product until you trail blaze it. Once you have created the solution, you can retrace your steps, and it will be much easier to practise once made explicit, but making a trail is a torturous path, filled with unknowns and risks.

That's why design problems are at best considered by those who have experienced them as wicked problems [Rittel and Webber 1973]. Although the Differentiation by Design process demonstrated in this last case will highlight some common design process heuristics that I have identified that are common to these design quests, this wicked nature of the design new knowledge quest versus practise of existing knowledge made previously explicit is necessary to research, learn and teach.

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Case History 3 - The Bionic Wrench

3.6 Bringing Focus to the Form and Functional Design Process

3.6.1 Getting to the Root Cause of the Problem

It is actually this mental modelling technique that I had employed in many of my past projects that led me to my pathway and inspiration for the Bionic Wrench mechanism; it was a journey, not a flash of lightning. To bring focus I started cognitively trying to seek and identify the root of the problem, in engineering this is called root cause analysis. Seeking a root cause I questioned why were the current tools damaging the fasteners. This happened by my mentally envisioning the work, cognitively playing out the scenario like a movie in my head. I find that I can actually visualise problems as a movie in my mind. My mental visualisations are both scenes that I have seen in life before, as well as scenes that I am creating in the moment. This process allows me to iterate and try various design options before pursuing them in more formal process, this modelling is often facilitated by sketching and other research techniques such as mock-ups and prototypes for deeper understanding of the challenge.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-6: Bolt Rounding From Stress Concentration Images From Web Search.

In this case, identifying the root of cause was not a difficult challenge, it was fairly obvious that the point load pressure directed to the fasteners' corners creates the damage (see Figure 3-6) as the user is applying as much torque to the work as possible to loosen or tighten the fastener. The focused forces are called point loads; this phenomenon is well known in engineering practise as a source of material failure. Point loading can damage metal or when used effectively can do work, as has evolved

Case History 3 - The Bionic Wrench

in the cutting tool discipline where we use mechanical point loaded tooling for machining on drills, mills and lathes.

Thus the question for my challenge was how I can reduce the point loading with a wrench design. Sockets attempt to do this, by spreading the point loads circumferentially around the fastener head, although sockets are often designed to engage the corners of the hex at the multiple points where the flats intersect but with six-point load locations rather than two for a poorly-engaged wrench. There is much more area on the flats of the fasteners to carry a load than the corners, but I needed a way to actively engage the flats even in conditions where the fastener sizes varied, as it was the necessity for wrenches to accommodate size variation that often exacerbated the rounding affect. With this insight, I focused on the active engagement of the fasteners for this challenge (see Figure 3-7).

There was another element to this problem, and that was how I could also actively engage the fastener flats to translate the forces with the rotational motion in a gripping fashion. This is what my son was arguing about, but not really being able to articulate as he was defending his pliers usage when we started on this journey. The pliers' squeezing action provides a secure grip of the fastener that is both assuring to the user but also provides a function of active engagement of the work piece. The pliers also easily adjusted, eliminating the need to know what the nut and bolt sizes precisely were, which my son was relying on, as he did not want to search for the right-sized wrench or socket. This root cause mental modelling brought functional focus to the design challenge, and I was able to identify the drivers of the root of the problem. These drivers became my functional needs for the design. Continuing the mental modelling and research, I was able to articulate these functional needs as beginning design performance requirements (see Figure 3-7).

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Case History 3 - The Bionic Wrench

3.6.2 Benchmarking the Form and Functional Factors

Hand tools have evolved forms adapted to work with the user's hand as well as perform the work the tool was designed to accomplish. For example, a hammer is adapted with a long handle to create leverage while maintaining control in the swing, and the head is adapted for impact and delivering the blow to the nail. In addition, the feature of the claw for removing nails evolved so that the head can be reversed to engage a nail by the head and the same handle that provided the lever for delivering the blow is now a lever for removing a nail. Understanding the basic usage and existing form factors that have evolved from existing solutions is necessary for bringing focus to the design process. While form itself is not set in stone and can itself become a strategic differentiator, it must do so in the context of the users endowed beliefs and behaviours surrounding the product experience. Understanding these user choice drivers requires research and analysis of the existing solutions.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-8: Bionic Wrench Holding Nut (Lau 2005)

I have been told that the unique design of how the Bionic Wrench symmetrically grips the fasteners has a form type mapping that communicates the unique engaging nature of the design (see Figure 3-8). In addition, the movement of the jaws as the handles are squeezed also distinctly contribute to the wrench identity and design language mapping and visual feedback for the wrench usage.

Case History 3 - The Bionic Wrench

3.6.3 Designing the Body of the Bionic Wrench

The use of wrenches also has some forms associated with them, as do pliers. It has been my experience that form does follow function as the saying goes. The needs of the form to actively engage the fasteners of different sizes and translate leveraged rotational force without slipping under normal loads was the primary functional requirement. The strategy was to do so on the flats of the fasteners versus the corners. Thus, the first step of the form evolution from the functional requirements was establishing the size of the wrench's head. There were a number of factors that played into this, the most obvious one was what size of nut or bolt head would the first version of the wrench cover.

In industry, it had been the long accepted standard to label the adjustable wrenches by their overall frame size. This identification convention was established and a common practise among retailers as well as users. These types of benchmarks are critical for the acceptance of your new product, and in design situations like this, it is important to adopt the industry or culture of your user group with your new product. It has been my design experience that change is difficult for people, and while your design relies on change for differentiation, you should only push that change process and resulting potential anxiety onto the stakeholders where it makes sense. Thus, it can be said that implementing a design strategy is often about change, but the designer should seek opportunities to build on the existing cultures and behaviours of the stakeholders wherever possible to reduce the level of change resistance

This was a bit of a conundrum; there were adjustable wrenches on the market, so I proceeded to benchmark them. They were typically sized by the overall length of the body, a standard that had evolved over the years. For example, an 8-inch Crescent Wrench was 8 inches from head to toe, and a 10-inch Crescent Wrench was 10 inches' head to toe. However, Crescent wrenches are adjustable over a range from zero to approximately 1.5 inches for the 8-inch body size. Typically, a smaller range is meant for the 6-inch body size, and larger for the 10-inch body length (see Figure 1-9).

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University	This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University	This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University
---	---	---

Figure 3-9: Images of Crescent Style Wrenches and Bionic Wrench Taken from Web.

For my hex sizing and adjustment range, I knew I should keep the frame size benchmarks of the industry, but my instincts were to look beyond the frame size for my answer, so I decided to look to the fastener market to see what the most popular fastener sizes were and their corresponding hexagonal flat face to flat face head sizes were. For this information, I headed to the local hardware store to determine what were the most popular bolt sizes purchased by users and what were the associated dimensions for the widths across the flats that corresponded to those sizes (see Figure 3-9).

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-10: Wrench Size Chart Accessed from Web at www.swifttips.com

Seeking to understand what the most popular fastener sizes were, I set out to go to the local hardware store. I asked several of the associates at the local Ace Hardware store what the most popular selling nut and bolt sizes were. After some discussion and a trip to the purchase records, they decided that the SAE 1/4-, 5/16-, 3/8-, 7/16-, and 1/2-inch bolt diameters were the most common around the house. This corresponded to a hexagonal head flat-to-flat size range of 7/16-inch on the low

Case History 3 - The Bionic Wrench

and $\frac{3}{4}$ -inch on the high side. The most popular sizes reported were $\frac{1}{4}$ -inch, $\frac{5}{16}$ -inch and $\frac{3}{8}$ -inch; this will come into play later in the reflection. I then went to an automobile store, I found them to be metric focused, and they reported a similar range with the corresponding metric hex head sizes of 11mm through 19 mm.

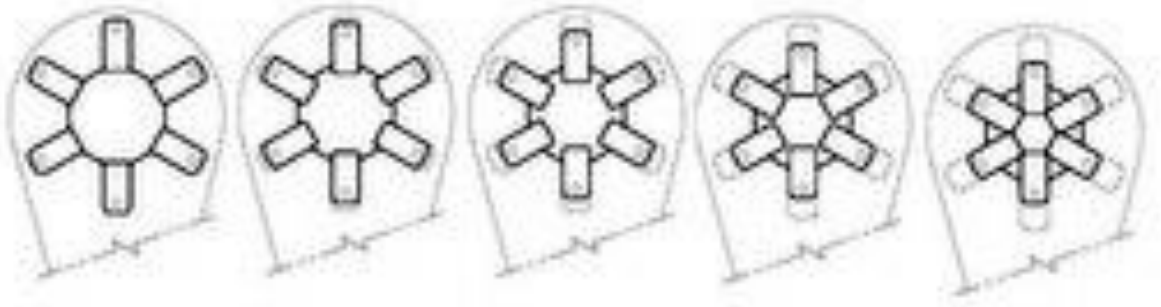


Figure 3-11: LoggerHead Tools Created Graphic

The data on bolt head sizes and the most popular sizes purchased provided me the information I needed to begin my design of the mechanism and components of the wrench. I had also similarly determined that the most popular frame size purchased for pliers and crescent wrenches was the 8-inch frame size. As I was seeking to conform to industry norms that both the retailers and consumers understood, and I wanted to target the most popular range size, I chose to focus the beginning of my design on the 8-inch frame. Next, I needed to determine the bolt head flat to flat adjustment range for this frame size. Based on the fastener purchase patterns that grouped from $\frac{7}{16}$ -inch on the low side, through and including $\frac{3}{4}$ -inch on the high side, I sought to try to accommodate this range with the 8-inch frame. The next step was to fit the jaw movement mechanism around the jaws and into the head of the wrench, my design focus at this point was to minimise the overall head diameter for the design, as many nuts and bolts have clearance issues.

Figure 3-12: Drawing Illustrating Jaw Pocket Optimisation from Brown US Patent 7,748,298

Following the analysis of this research, I went back to my CAD modelling and began creating a mechanism model to accommodate a 3/4-inch hexagonal head at the high side and 7/16-inch on the low side. This required an overall jaw travel of 5/16-inch ($12/16 - 7/16$), but fortunately the jaws were converging so each jaw would only need to travel 5/32 of an inch (each jaw traveling 1/2 the distance as it converged). As I was building the model based on these parameters, the overall circular specifications of the head were evolving. Based purely on the known dimensions, the head was already 3/4-inch plus another 5/16 of an inch for jaw travel without any other structure, which was necessary this was already 1-1/16-inch diameter for the head.

I needed to both optimise the jaw movement interaction and sizing with the wrench head to allow for adjustment, gripping strength and maintaining a minimal head size so that the trade-off of a wide adjustment range would not create an overall wrench head size that would be objectionable to an adjustable wrench user. The following optimisation steps were simply repeated modelling of the slot angles and arcs based on the ranges I had identified in CAD, and adding the structure required for the inner and outer plate interaction allowing for sufficient strength. The next important steps were to determine how to design the jaws to interact with the plates, and how to design the force transfer elements that coupled the jaws to the inner plates.

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-13: Brown 579' & 298' Patents

I had to not only design the slots for the jaw movement (see Figure 3-13 number 46), but I also had to allow for slots in the separate plate design to allow the head rivets to pass through (# 32). I had two options to extend the slot that followed the circumference about the central access of the wrench head under the slot for the jaw, or above the slot for the jaw as shown above. I eventually chose the slot for the rivets (58) in the above orientation. This arose out of the optimisation of the jaw inner plate nesting and optimisation in CAD. As can be seen in the jaw progression images below.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-14: LoggerHead Drawing of Jaw Movement as the Inner and Outer Plates Counter Rotate

By moving the slot for the rivets above I was able nest the jaw body into the head profile in a tighter orientation, optimizing the use of space. In addition, I needed to allow enough web thickness at the thinner stamping sections, thus the positioning of the outer circumference outside the circumference of the rivet slots, allowing for a ring of steel in a web thickness to handle the mechanical stress, and allow for stamping without deformation. The final head diameter came in at 2 inches, allowing the wrench to work on fasteners with a 1-inch centre point clearance. This was an iterative process of first researching the requirements and optimizing the functional drivers in an iterative series of modelling and prototyping in order to establish an optimise design specification with the minimal amount of trade-offs.

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-15: Final optimization of slots and jaw pockets [LoggerHead Drawings](#)

Optimising the design and relationship of the inner plate slots required a lot of design work. First, the travel of the force transfer element along the slot had to move radially from the centre for $\frac{5}{32}$ of an inch in all six directions. As the bolts were hex, I decided to use six jaws, but I also had the option of using three jaws and shaping the jaw head with a 120-degree V shape capturing the head from three converging positions on 120-degree complementary paths but at the same time contacting the six flat surfaces from the three attack points. As I wanted to avoid directing forces to the corners, I chose to engage the flats from all six directions to maximise the load distribution onto the flats.

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-16: LoggerHead Literature wrench sizes for the 6-inch and 8-inch Bionic Wrench

Planning for the future, I also needed to consider the sizes for the smaller and larger wrenches; from my research into the market, the 6-inch overall frame size appeared to be the next logical step. The obvious choice would have been to design the head mechanism so that where the 6-inch wrench size stopped; the 8-inch wrench size would begin. My design rationale did not follow this logic; at this point I had realised that the majority of hex heads that users would see was in the range of 7/16-inch to 9/16-inch. I understood many users would not purchase both wrenches, so I

Case History 3 - The Bionic Wrench

decided to overlap the 6-inch frame and 8-inch frame so that either wrench would cover the most popular-sized nuts and bolts. Thus, as can be seen above, the 6-inch frame handles up to 9/16-inch and the 8-inch frame can go down to 7/16-inch dimensions.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-17: Brown 298' Patent

As seen in the image above (see Figure 3-17), there were also considerations for an open version early on in the design process so that the tooling would accommodate the product family evolution.

3.6.4 Bionic Wrench Alternate Body Design Styles

As in the other categories, several body styles were accessed, the ultimate body style arose out of the functional drives of the plate production process. Choosing four plates for the body style determined the path; the first question was to use straight handles as in typical pliers or the angled handles as many pliers have moved to. There was some modelling in CAD for style, but the design decision was based on user testing and response. I acquired two similar pliers' tools, and asked users to try each and share with me their preferences. The angled handles were the winners by far, in comfort, look and feel. I then sought out the best way to make them comfortable.

3.6.5 Bionic Wrench Alternate Handle Design Styles

The torqueing under load puts stress on the user's inner fingers so I sought out a cushion grip supplier. I chose a style of vinyl dipping that was common to the tool industry, this style was a two-step process. The first step was a solid layer,

Case History 3 - The Bionic Wrench

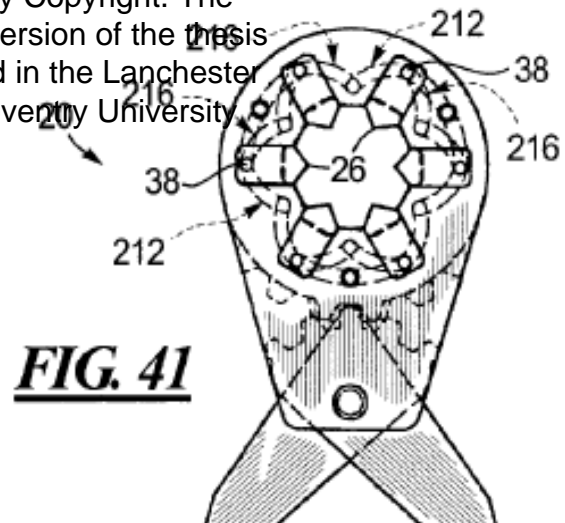
immediately followed by a second dip, which allowed us to both change the feel of the handles as well as the colour. First, the second dip was of a vinyl that had a chemical blowing agent mixed in, thus when the vinyl cured in the oven it expanded into a softer feel and cushion-like skin. These handles are common, almost a commodity item for hand tools, the one problem was that the forward handles were half the thickness of the rearward handles; this was not only less comfortable, but also not visually pleasing or balanced. I asked the supplier what could be done, and they recommended for a small price premium they add ribs into the dipping moulds that would add additional thickness and cushion to the forward handle. I prototyped both and tested with users, the thicker forward handle was universally preferred.

3.6.6 Designing the Mechanism of the Bionic Wrench

Optimising the jaw design to interact in both a functional and form embodiment that optimised the wrench design followed a path of modelling various types of jaws for both wrench tools, but also anticipating other jaw embodiments for future tools (see Figures 3-18, 3-19 and 3-20). The design mechanism of jaw movement allowed for the plates to work in different configurations by changing the jaw styles. My work at this time required me at first to mentally model, design in CAD and later through prototypes development and testing the various interactions of the plates and jaws in use. The design relied on the rotation of two plates to create the jaw movement and force translation. One plate has a series of radiating rectangles placed symmetrically about an axis, and a second plate has a series of slotted curves symmetrically about an axis. When combined together, their counter rotation to each other causes the force transfer elements and the jaws attached to them to move inward and outward radially.

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University



This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-18: Plate Jaw Interaction Examples Taken from LoggerHead Patents

During the design process, there were multiple design iterations considered and again optimisation was necessary to identify the best combination for the particular design embodiment. Below is a wrench with opposing curved slots to drive the jaws. The combining of the plates allows for variations of tool embodiments, for the wrench embodiment the choice was primarily to have the curved slots as the inner plates (as the first production wrenches did), or on the outer plate. Basically, the same design but one jaw would be U shaped and the other would be solid as seen below.

Case History 3 - The Bionic Wrench

The combinations of the plates with other jaw styles allowed for the possibility of product line extensions in the basic product format with the possibility of using similar materials, components and manufacturing processes to build a product line of tools.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-19 :Patent Drawings Showing a Folded Outer Plate, Single Inner and Outer Plate Variation

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-20: Brown Patent Drawing Showing Variation with a Solid Inner Jaw

Case History 3 - The Bionic Wrench

As can be seen from the historical patent data, there were many variations on the plate activation method for moving the jaws. The decision on the first commercial embodiment was based on a number of factors that must play out in the design and development process, function drivers, manufacturing process drivers, form optimisation as well as cost drivers. The creation and mental and physical modelling of these interactions are an essential step in the creative process, the most important aspect is that the designer works both with the suppliers as well as the users in order to manage the trade-offs that each particular design choice creates.

3.6.7 Designing the Jaws

Similar to the jaw movement mechanism in the plates, the jaws are another critical component of the wrench, choosing the optimal form for performance, cost and manufacturing process was challenging. The jaws must handle the engaged workload of the work, fortunately there are six jaws for maximising the force distribution and work engagement, thus the load carried on any one jaw and force transfer element is $1/6$ of the total load. The downside to this is that six jaws require more cost than three jaws, which was lower cost but the design trade-off is each jaw would be required to carry twice the mechanical load versus a six-jaw version. Although three jaws are a lower cost option, I judged that the trade-off in load distribution and engagement compared to the six jaws to not be worth the cost savings (see Figure 3-21).

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-21: LoggerHead Patent Drawing Depicting 3 Jaw and 6 Jaw Designs

Case History 3 - The Bionic Wrench

Some early jaws were a little more complicated with wing-type extensions that extend from the jaw face and provide more reach (see Figure 3-22). In addition, I considered notched V jaws that would engage the corners of the fasteners as opposed to the flats as seen below.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-22: LoggerHead Paten Image Showing Extended V Style Jaws

The process of choosing an optimal jaw design came down to building various jaw prototypes and testing them on nuts and bolts as well as users. The testing results are then analysed in the context of the jaw cost in a trade-off type analysis seeking the best option, or in this case performance value.

Thus optimising the jaw cost was critical. After working through a number of jaw configurations, I had narrowed the design to two probable orientations depending on the design strategy; one possibility was to have the slotted plates as the outer plates with a solid jaw, or put the slotted plates on the inside and have a U-shaped

Case History 3 - The Bionic Wrench

jaw. We patented both orientations, but in the end, I chose the U-shaped jaw basically because it extended the whole width jaw engagement of the fastener to the complete width of the wrench, thus allowing for more jaw area to reach the fastener. This is true especially when the fastener was up against a flat plate.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-23: LoggerHead Patent Depicting Reversed Plate Design

Quotes for all jaws were coming in too high. I was getting quotes from traditional machining processes and although a simple shape, the force-transfer receiving hole tolerance, an amount of machining required to remove the centre material and hold tolerance was expensive. I could not bear this expense with six jaws on each wrench. Working with the suppliers, I could not get the cost low enough. I knew there had to be a better way to machine these jaws. I decided to go to the IMTS (International Machine Tool Show) at McCormick Place in Chicago to talk to the machining experts and see if I could find any possible solution. This turned out to be a pivotal trip in the development of the Bionic Wrench for two reasons that will be discussed further when discussing choosing component suppliers. In addition, there were many jaw variations envisioned and tested to explore the design and potential new tools to be created.

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University



3.6.8 Designing the Component Tolerances

Dimensioning and tolerance are two very challenging engineering tasks in new product design. The designer can greatly reduce the challenge of the engineer and component suppliers through the design choices made early in the design process. The design choices follow the Lean Design strategies of reducing the number of components, using standard components wherever possible and decouple the tolerance stack-ups in component interactions. Design choices have to be considered in light of the manufacturability of the components in production. The challenge is to

Case History 3 - The Bionic Wrench

optimise the designs performance without sacrificing the ability to reduce the cost, I have found that it is critical do continuously evaluate these trade-offs in the process.

The first challenge for the designer is to decouple the component interactions whenever possible to minimise and eliminate occurrences of tolerance stack-ups. This can be seen in the Bionic Wrench design by the independent nature of the jaws working together but separately in each individual interaction with the plate mechanism. Using only one spring versus the multiple lifting springs under each jaw of crimper-like devices also decouples those jaw-spring interactions, as well as decreases the number of components. To optimise the design to get the most benefit from the components:

- Reduce the number of parts
- Standardise parts
- Standardise processes
- Design parts to be symmetrical
- Design so that the parts cannot be assembled incorrectly
- Design the parts to take advantage of supplier experience and buying power

The design is so decoupled with the jaws that one can remove them and the basic operation will continue for the wrench. The next design area that has a great effect on the manufacturing tolerance challenges is choosing a subcomponent manufacturing process that can easily produce to the tolerances you need, not a process that is stretching its capability. Having designed out the obvious problems, what is left is to analyse the assembly and establish the tolerance minimum and maximum dimensions that will allow for reliable assembly and quality performance.

One area that cropped up as a problem for me was the tolerance for the two force transfer holes in the jaws. Under normal conditions, holding machining tolerance for these holes is a standard drilling operation. For the jaws, I wanted to choose a corrosion coating that allowed me to colour contrast the jaws with the black oxide of the body. From a form perspective, I believed that the prominent jaw contrasting like shining teeth against the body would provide a strong visual experience. Most commercial coatings are not easily to pigment, thus there is a limited range of colours and most tools have similar looks because of their common coating choices.

Case History 3 - The Bionic Wrench

I was looking to differentiate here with the jaw coatings. In addition, the traditional heavy metal-based coatings like cadmium plating, and zinc-based electrochemical processes were becoming regulated in the United States and are not very environmentally-friendly. Thus, I chose to pursue a new and more environmentally friendly coating technology that also had the advantage of being coloured. Working with this supplier we prototyped a number of colours, and I chose white grey to contrast the black of the body. We built prototypes with these jaws and everything was fine until the first production run.

On our first production run, the force transfer rivets did not easily go into the jaw holes, at first we thought the jaw supplier made the holes too small. After analysis, we found that this new coating process had a tendency to build up on the inner diameter walls of the holes in an uncontrollable fashion. This coating build-up was very hard in nature although minor, and under normal circumstances caused the jaws to break when the force transfer element was inserted and riveted. We found that this jaw coating process, although good in all other areas, was just too unreliable for this application. These types of start-up issues seem to always pop up as not everything can be sorted through in prototyping. Thus, we quickly migrated to another coating process that was also environmentally friendly but more expensive. We did get a benefit of bright and shiny jaws, which really enhanced the look of the wrench.

3.6.9 Choosing the Best Value in Hardness and Coatings

While performance issues will be the first driver of mechanical strength and corrosion resistance, benchmarking industry standards is often the best way to bring a focus to specifications. Quite often the industry standards must be met as they are often written into countless quality, environmental, safety and other documents that co-evolve with technology. The designer's desire to incorporate the latest technology into a product design can often get sticky when the challenge of testing and validating that the new technology meets the industry standards and specifications becomes overwhelming. In many cases, old standards remain in place and unchanged simply because there is insufficient demand to update or change them. Thus, researching these standards, and accessing those that are non-negotiable is an essential early design research process. Standards that cannot be changed become design constraints, requirements that must be met by your new design.

Case History 3 - The Bionic Wrench

Suppliers are a good source to the understanding of the industry specifications as often time's suppliers and component manufacturers specialise in particular industries. This specialisation allows them to develop an expertise in specification benchmarks for the industry and can be not only a great resource of information, but they often have in-house testing capabilities that you can use for little or no cost when you are working with them. When seeking a supplier, my research determined that the retailers did not insist on a specific quality program such as ISO or Six Sigma, etc. What they required was that the products meet the ANSI specifications, and that the products be tested by a third-party agency to certify quality and safety.

This allowed me flexibility to adapt my quality system to my eventual supplier, which is an important strategy. As I have learnt that suppliers will tell you they can use X or Y quality system to get your business. However, the dominant supply culture will be that of their largest customer group, and this is the system that will be audited and sustained. You can design your quality system around the one the supplier is an expert in and have established in their culture. For the Bionic Wrench, I used the ANSI specifications for corrosion and hardness.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Case History 3 - The Bionic Wrench

Part of the need finding research involves looking forward to commercialisation and researching early on in the process those needs in the forms of industry standards such as quality, performance and others that will be required for your new product. These standards affect everything from performance metrics, to packaging, to your ability to get insurance. For the Bionic Wrench, I was challenged to seek, and identify the following standards-related metrics and benchmarks that become fixed design requirements or often called constraints.

3.6.10 The 579' Brown Patent Outlines the Design Problems

As a result of manual operation, self-energizes the tool action, may be automatically sized and resized to engage a workpiece; de-energizes upon release of actuation force, that has a broad range of dimensional capability; engages workpieces axially and radially and provides offsetting forces for stability in operation; symmetrically translates the force applied to the gripping tool onto the workpiece in a symmetrically-balanced and mechanically-advantaged and efficient way; even distribution of gripping and rotational force about the workpiece is achieved, whereby allowing for the most efficient distribution of mechanical stress about the work piece; accomplish the work with minimal distortion of the work piece by distributing the work force over the largest area of the work piece.

Other advantages of the adjustable gripping tool of the present invention include decreased costs; increased productivity and multi-access engagement of the work piece resulting in a mechanically-advantaged, efficient, even and balanced distribution of working forces.

3.6.11 Choosing the Best Value in Material

Material choice for the body and the jaws required the balance of the manufacturing process choice with the best material to optimise that process. The final chosen process for the bodies were a 1070 Steel that was developed for automatic stamping presses. The steel is annealed so that during the processing it is in a softer-than-normal state for stamping. The thickness of the steel is a critical choice for stamping, the combination of thickness, hardness, and strength of the alloy all must combine for a design choice that works with the process. Once stamped, the

Case History 3 - The Bionic Wrench

material is then hardened in a secondary operation to gain fracture toughness. Fracture toughness is defined as a material's ability to resist the propagation of a crack. The knowledge of this choice and the trade-off analysis to arrive at this choice evolved through working with manufacturers who are experts in these processes. Working with potential manufacturers early in the design stage where your interaction can optimise the sub-component manufacturing process and material choices is critical for developing and managing both investment and overall manufacturing costs.

Choosing the best value in material must be considered in the manufacturing process; another important element is choosing a material that is readily available, preferably in large quantities and not a specialty material. If the material is common, it is more likely to be reasonably-priced versus a specialty material. If the material is a specialty material, it will not only cost more, but it will be harder to procure, creating longer lead times, and often require higher purchase quantities as the supplier does not like to keep a stock of specialty materials. I have learnt that it is a good strategy to keep the material question in mind when choosing a supplier. As suppliers develop expertise with certain materials that they run all the time.

In addition, they often buy larger quantities because they use the same material on other projects, allowing them to have more purchasing power with the supplier. Structured properly, you can allow these savings to pass through to a project. For the Bionic Wrench project, I actually switched from my original material to a similar material that the supplier liked and had a lot of experience processing. This allowed me to take advantage of the above material strategy for the commercialisation of the Bionic Wrench.

3.6.12 Choosing the Best Manufacturing Process

Commonly discussed as Lean, Design for Assembly (DFA) and Design for Manufacturing is a process by which products are designed with ease of assembly and manufacturability throughout the design process. The sub-component manufacturing process, material and strategy co-evolved with the Bionic Wrench design. Without thinking about manufacturing, it is quite often possible to design yourself into a corner when it comes to production. If this is found out late in the

Case History 3 - The Bionic Wrench

development process, there is a potential that you would have to redesign for manufacturing, causing you to retest, and even possibly completely redesign.

My first benchmark process was stamping and using a plate manufacturing process similar to the Robo-Grip pliers (see Figure 3-27). I liked this design as it allowed for precision components that can be mass-produced, also there were many stampers doing high quality work for many industries such as automotive and appliance products. Several other processes that could produce net shapes similar to stampings for the plate design were laser cutting, water jet cutting and wire EDM machining. While these processes each had their trade-offs, none of them could compete with stamping on a piece part cost, but with the trade-off of a large capital tooling expense for the stamping dies invested upfront.

At this point in the process, I worked diligently to try to get the non-tooling dependent costs down but the process automation of stamping and maturity of the supply chain produced the lowest cost wrenches. As my benchmark product was the Robo-Grip, I was basing my product forecasting on producing millions of units, thus there was a large enough unit volume to amortize the tooling costs, although the prototypes and first short run production utilised water jet cut plates when we required parts prior to the creation of the tooling (see Figure 3-26).

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-26 LoggerHead Patent Example of Stamped Plate Manufacturing

Choosing stamping over the other manufacturing processes for the plates also required considerable engineering meetings with the tooling designers in order to optimise the design to accommodate the needs of the stamping process. Beyond creating tooling for the first size Bionic Wrench, which was the 8-inch overall length version, future product variations that would require a variation in the tooling must be considered (see Figure 3-27). At this time, I had envisioned an open-headed version of the Bionic Wrench, as well as a multi-tool version to be developed and released later in the business cycle.

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-27 LoggerHead Plate Manufacturing Design

It was necessary to work the logistics of this through with the tooling designers so that the tooling purchased for the Bionic Wrench would have the capability to create what eventually became the Bionic Grip. Another example of this product design strategy can be seen with our 6-inch Bionic Wrench, the same tooling creates the Bionic Wrench, Bionic Grip and ImmiX Multi-Tool plates. This required planning the future stamping steps early in the design process so the tooling built for the first product could be later modified to create the multiple products with minimal additional tooling investment (see Figure 3-29).

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-28 LoggerHead Patent Drawing of Bionic Grip and ImmiX Plate Stamping Manufacturing

3.6.13 Line Extension Design

One area that I identified early on for a potential line extension was an open-ended version of the Bionic Wrench, the eventual product created is called the Bionic Grip. The Bionic Grip is a unique product in its own right, but a direct descendant of the Bionic Wrench. The Bionic Grip was created to compliment the Bionic Wrench and address those use situations where you had inline pipes and fittings that required an open-ended access (see Figures 3-28, 3-29).

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-29 Line Extension for the Bionic Wrench Family (LoggerHead Tools 2005)

Case History 3 - The Bionic Wrench

Another line extension was targeted as a Professional version; we had identified better corrosion resistance and an integrated locking mechanism as potential differentiators for professionals. As a result, we modified the existing tooling to accept a patented interlocking design in the existing body that did not rely on a secondary operation. Simply the forward handle acted as a living spring under load and bit down onto the gears attached to the body plates.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-30 Line Extension of an Interlocking Version of the Bionic Wrench and Grip

3.6.14 Platform Design

Platform design builds off the concepts of expanding your product offering by designing ways to sell more of your design in different but complementary configurations. As in many of the other examples of this case history, the designer must think ahead to future platforms when designing the product, choosing the materials and manufacturing processes. The Bionic Wrench utilises the platform design strategy in the following ways (see Figure 3-31).

The basic wrench design was scalable, so scaling down the Bionic Wrench to a 6-inch body, and scaling up the Bionic Wrench to an 8-inch body without design or patent changes was achievable. The closed end version of the Bionic Wrench was produced first, but the open-ended version was envisioned. Thus, the tooling for the closed end was designed and built to accommodate the open-ended version.

This was extended a step further in the 6-inch body style, as I had envisioned a multi-tool version of the wrench both open- and close-headed. The 6-inch body style tooling was designed and built to accommodate this. The open and closed version do not share the same jaws as they share the same body tooling because the open version is used primarily for engaging pipe, thus the jaw face has teeth. Both the open

Case History 3 - The Bionic Wrench

and closed versions of each body style share springs, handle grips, body steel, fasteners and packaging except for insert cards

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-31 Line Extension Design Examples from LoggerHead Literature (LoggerHead Tools 2005)

The sharing of many components and tooling pays off in the end by reducing tooling investment and inventory carrying costs, but it is a challenge to be tasked with looking into the future while still developing the initial version. Creating a platform requires more than just graphical extensions of the original product. The Bionic Wrench was the product design that established the founding product mechanism. Extending the use into an open-headed hand tool version was a logical extension although it was not a simple change. Removing two of the jaws to allow for the opening up of the head of the tool changed the holding strength of the design. Essentially the gripping power of four jaws did not provide the mechanical advantage of six jaws. This physical change in engagement of the work required a change in the design of the mechanism.

The need to enhance the gripping power was originally contemplated in the first patent, and a lock version of the design was contemplated at first. Upon user testing, I realised that for typical home use there was no real advantage to having a separate lock. Thus, the original Bionic Wrench was launched without a lock, as it exists today. When I was validating and testing the open version Bionic Grip, I found that I needed to have the additional holding force because of the loss of the two jaws. This forced me back to the drawing board, but with the knowledge that a separate lock was not desirable in the past, I sought to create a lock that worked without changing the user's behaviour. Thus the new lock that we commercialised works one-handed, it locks under load in use, and releases when the handles move apart during re-gripping.

Case History 3 - The Bionic Wrench

3.6.15 Mass Customisation Design

Mass customization is a process where the manufacturer can easily change the look of a product to meet the identity and marketing requirements of the marketplace. While our strategy was to create our own identity and brand in the marketplace, we realised that there could be possibilities to co-brand our Bionic Wrench under another tradename in markets where this made sense. We realised that this could produce some opportunities especially in foreign markets. The Bionic Wrench could be mass customised in the following ways:

- Handle colours could be changed
- An endorser brand could be added to the Bionic Wrench brand
- Packaging inserts customised to an endorser brand identity

The images below are examples of our first truly large customer during our first and second year, we mass customised by maintaining our product brand name, but co-branding with their well-known and recognised brand in Canada.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-32 Mass Customization Design Images from LoggerHead Literature (LoggerHead Tools 2005)

3.6.16 Colour Scheme Design for Identity Among the Competitors

For the Bionic Wrench development, I had independently developed the design, and owned the patents, I also had Lean-designed and optimised the design to the best of my ability prior to choosing my supplier. Similarly, I had also tested and validated the design and marketplace validity in the design process. While nothing is guaranteed, I did raise the certainty of success, and I secured that security with Intellectual Property early enough to know I was in a strong position. Having done the

Case History 3 - The Bionic Wrench

design work at the highest possible level, I was not approaching the suppliers from a weak position of need, but with a viable product potential for mutual success for both our businesses. With this power I was able to negotiate between multiple manufacturing partners in order to get them to put some skin in the game for this project, a lesson I had learned long ago, when everyone has skin in the game, it is not so easy to quit when the going gets tough, and the going always gets tough! I will discuss the other needs that I pre-negotiated with my supplier early on as conditions for moving forward as Strategic Partners.

3.6.17 Trade Dress Design Strategy

This recognition is described by the IP community as secondary meaning, the acknowledgement by the community that your trade dress is unique to you and the dress identifies your company and your product through the design language that evolves from your business. If you are creating a new product, new company and product identity as was the case of the Bionic Wrench, the designer must also create the identity and dress of the new company/product experience that will eventually evolve into a formal trade dress based secondary meaning with the stakeholders if successful.

Trade dress relies on the acquired meaning in the marketplace created by the consumer recognition of the product within the competitive commercial space. Quite often in the development process the functional disciplines of engineering, design, manufacturing, quality and marketing are working in a silo mentality within their organisations. This silo disciplinary view of the new product development process is inefficient and quite often counterproductive to the objectives of the organisation. Recent discussions of multi-disciplinary teams working on the design and development process have risen as a result and recognition of this problem.

In large mature organisations, the compartmentalization of functional disciplinary activities follows an organizational efficiency strategy of systematizing the work. While this may in fact work for existing established products and brand identities, it does not facilitate new product entrants that must also create a brand. Logically it is unlikely that a pioneering product will have a cohesive brand identity in the future, if it is not designed into the product in the design process as a strategic

Case History 3 - The Bionic Wrench

design language. The LoggerHead packaging design language created with a view to the future can be seen below (see Figure 3-33).

This item has been removed due to 3rd Party Copyright.
The unabridged version of the thesis can be found in the
Lanchester Library, Coventry University

Case History 3 - The Bionic Wrench

3.6.18 Identity Design Logo-Mascot and Strategy

Launching a new product out of an existing business that has an established identity in the marketplace allows the designer the option of extending the new product experience from the existing company/product identity and trade dress. Trade dress is a form of Intellectual Property and can be described as the recognition of your company and product experience by the stakeholders in the marketplace. The look and feel of McDonalds, Starbucks and other businesses is the result of this design language that has established identity-based meaning for stakeholders.

Seeking to build on this area of product design, I sought to create a product name, colour scheme, packaging scheme, company name, tag line, and business model that all integrated in a well-designed fit for our new product and company identity (see Figure 3-33). I was tackling this challenge in late 2004 and early 2005 as we were scheduled to launch the product at the National Hardware Show in the spring of 2005. Although we were actually in talks with Sears at the time, and they wanted Craftsman branding and us to give them the Bionic Wrench name, I continued the independent development of our own identity (see Figure 3-34) in case the Sears thing did not materialize. This was fortunate, as we were negotiating with Sears, K-Mart's owner Eddie Lambert had taken Sears over and our discussions had ceased because of all the uncertainties happening at Sears. We had booked our space at the show, prepared our identity and marketing materials and even though the Sears deal ended, we were still ready for our market introduction in May 2005.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Case History 3 - The Bionic Wrench

3.6.19 Company Name, Imagery, and Logo Design

I wanted a memorable name that had a metaphorical meaning, interesting feel and a suggestion that we were a tool company. I had heard a story before that there was some social science research that had demonstrated that humans had a higher capacity to remember animal names and images. I do not know if this is in fact the case, but the anecdotal part of the story was that because of this capacity to remember animal names, the automotive companies named their sporty cars after animals in the 1960's, for example Mustang, Jaguar, Cougar, etc. Thus, I was brainstorming animal-related company identity and product identity names for what I had been calling the CT wrench during the development, Consul-Tech wrench after the name of my design consultancy Consul-Tech Concepts, Inc.

I had difficulty finding metaphorical animal names that were not already registered tradenames. Therefore, I brainstormed some other ideas like powerful jaws and did a Google search. The results were the usual actors Alligator, Crocodile, Shark, Piranha etc., but I came upon an unusual and unfamiliar name to me, and that was the Loggerhead turtle (see Figure 3-35). A little research about the Loggerhead turtle revealed that although they did not have the most powerful jaws in the sea, they were considered very powerful, as the turtle would eat shellfish by crushing them. I continued to search the term Loggerhead and found a reference to a tool that was referenced by Shakespeare's writings referring to a bulb of iron with a long handle, used, after being heated, to melt tar for sealing the wood when building sailing ships. I remember that it struck me that there was both a tool reference, as well as long handle large head reference, both of which can be metaphorically associated with the Bionic Wrench.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-35 Early LoggerHead Identity and Company Name With Tag-Line

Case History 3 - The Bionic Wrench

3.6.20 Product Names Design

My research into animal names for the CT wrench (development name, abbreviation for Consul-Tech wrench) started with ways to use the animal meme or identity to suggest the circumferential movement and gripping of the jaws. While Loggerhead worked as a company name, calling the wrench the LoggerHead Wrench did not work for me so I continued on a search for a product name.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

After mocking up the identity, brainstorming name, testing on people, searching the Trademark database to be sure we were in an open space, we settled with Bionic Wrench. At the same time, we saw the extension of the name for the open version as the Bionic Grip. Upon reflection, these names did seem strange, but as the popularity of the design caught on and the use became prevalent, the name acquired a meaning.

This item has been
removed due to 3rd Party
Copyright. The unabridged
version of the thesis can

Case History 3 - The Bionic Wrench

3.6.21 Packaging Design

I benchmarked the existing competitive packaging in the marketplace, while many commodity tools were simply hung without packaging with labels to save money I rationalised that a new product needed the billboard effect for communicating our value proposition. The standard was a clear clamshell with an insert card, thus I set about designing the clamshell that would accommodate the wrench, and fit in the retailer's footprint that was allotted on the hall for the product category. This process was a CAD process of creating the clamshell shape to accommodate the wrench, one unique adaptation is that I wanted the users to experience the wrench while in the package. Thus, the plastic shell was designed to allow the users access to squeeze the handles, and put their finger within the head and feel the jaws through an opening on both sides.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-36 LoggerHead Retail Packaging Design

Beyond the retail package, I had a similar challenge in creating a merchandising packaging strategy that would coordinate with the needs of the distribution channel and their different sales strategies as well as internal material handling and distribution strategies (see Figure 3-36).

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-37 LoggerHead Retail Packaging Merchandising Design

Beyond merchandising displays that allowed retailers to buy a 12-piece display or a 96-piece display, there are requirements for multiple product merchandising configurations. The challenge is to design a packaging strategy that is modular and can be easily adapted to the particular retailer's requirements without recreating all of the packaging from the ground up. Packaging is expensive and is often a large hidden cost in the overall product cost and shipping. In addition, your packaging is your billboard for communicating your value proposition to the customer at the point of purchase (see Figure 3-37).

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-38 1 Example of LoggerHead Multi-Product Packaging and Display System

Case History 3 - The Bionic Wrench

3.6.22 Choosing the Best Component and Manufacturing Partners

Once I had optimised the design and decided on plate manufacturing process, I needed to choose a stamper. However, my strategy for producing the product was not a vertically-integrated process where my commercialisation plan was to manufacture the main components, assemble and sell the products. I had set the goal of producing the Bionic Wrench in the USA, this was a design goal, but not a design goal based on the existing competitive products in the marketplace.

The competitive products were virtually all made offshore in low-cost manufacturing environments, it was a big risk but I chose a Made in USA strategy to further distinguish the new value and advantage of the design. I have forever worked on the marketplace premise that a better product will support a better price. I believed that I had designed a better product and that if my Lean Design was optimised, I would be able to make the products in the USA and sell it for a value-added price.

This caused me to bring considerable focus to the Lean Design process as well as the manufacturing strategy that I was to rely on. Choosing the best manufacturing partner was a critical part of the design process, not just for the Bionic Wrench but also for all new product designs that have sub-components and production assembly and distribution. Many companies have simply evolved by shipping the manufacturing offshore and letting the suppliers sort out the problems. I on the other hand had to pay great attention to this aspect of the design as it was critical to the viability of my market and competitive positions. Beyond the Lean Design optimisation, I had another set of conditions that I needed in the supply chain in order to optimise my commercial viability by managing my risk. I had experienced instances in my past work where a separated supply chain created unnecessary confusion when problems arose. When the inevitable problems arise in product around quality, performance or other operational matters, the more people in the problem the more difficult it is to quickly sort out and solve the problem.

I determined that the body plates supplier would be my most critical sub-component supplier in the supply chain, this was based on a number of factors, most importantly was piece part cost, and the quality of both the stamping as well as the flatness of the plates. Researching and determining these critical sub-components in your design are essential for sustaining your product in a competitive marketplace.

Case History 3 - The Bionic Wrench

My strategy was to find a stamper who could provide all of these services in-house; design and build the stamping tooling, do the stamping, and act as the final assembler of the products.

My rationale for this was simple but important. In cases in my past where a manufacturing strategy did not manage these processes when a problem occurred, the separate entities started blaming each other for the issues, rather than focus on solving the problem. While the finger pointing was going on, the problem was not getting solved and it remind me of the situation of having three kids fighting in the back seat of a car ride. Understanding this dynamics and not intending to get in the stamping or assembly business as part of my business model, I only considered stamping suppliers who could accomplish these services. As it turned out my final choice for the manufacturing also had direct experience building the RoboGrips, the product I was benchmarking my Bionic Wrench on for marketing purposes.

The ability for me as the designer to have power in this relationship for negotiation of the best terms was directly related to several key design strategies I employed. I have found these strategies to apply almost universally in product design. They are founded on the logic, the relationships and decisions you make as a designer throughout the design process often are anchored into your reality, which is, you do not often get a chance to transport yourself back in time to reset the clock or terms of your relationship. If a supplier knows that they have you in a corner, they will be less likely to be flexible with you on aspects of the relationship that have to do with a number of areas. Thus, your power to establish the working relationship conditions is when the supplier is competing to become your supplier with your other candidates that you have to co-develop throughout your design process.

3.6.23 Intellectual Property Design Strategy

Beyond seeking, conceiving and creating a commercial new product experience, the designer must recognise the cannibalistic nature of the competitive marketplace. Simply without a strategic barrier to entry, competitors seeking to profit off your design work once you have created the market for the product will quickly copy your design and bring the copy to the marketplace without having made the investment of time, effort and money required for a pioneering new product effort. These barriers to entry can arise among several areas, for example, you may have

Case History 3 - The Bionic Wrench

control of a strategic technology or resource, you may control the manufacturing process or distribution channel or you may have some form of monopolistic position in your market. In the absence of any of these barriers to entry, the designer must strategically seek, conceive and create multiple forms of intellectual property to secure and protect their rights to their designs in the marketplace. These strategies are designed and established through Intellectual Property protection; Copyrights, Trademarks, Trade Dress, Patents and Trade Secrets. The specific strategy is itself a significant design process and it must be created within the context of the technology and the marketplace. LoggerHead employed a multifaceted intellectual property strategy in order to secure the rights to its creations as seen in the Intellectual Property summary below, and in the body of the design discussions of this case history.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Case History 3 - The Bionic Wrench

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Case History 3 - The Bionic Wrench

3.7 Reflection on the Designed Solution

As discussed in detail earlier the design process for the Bionic Wrench was much more than a traditional engineering design project. While the engineering work was essential to the success, the product would not have been able to scale in the marketplace without the additional customer getting differentiations designed into the product experience. These differentiations discussed previously evolved from a strategic design process that incorporates a stakeholder-centric and empathic approach to problem finding, need finding, benchmarking research, seeking of unmet needs, creating novel solutions into white spaces that can be protected. This design process also incorporates the design of those value creators beyond form and function that contribute to the overall competitive advantage of the product experience and leverage the supply chain, business model and distribution channels. Collectively this case history experience has achieved significant recognition and validation by the design and business community as seen by the list of awards below.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-39 Award Descriptions at <http://www.lhtmediakit.com/awards.html>

Awards are great and they can serve a purpose of creating product awareness through PR (Public Relations) that can be a very powerful identity creator in the marketplace, but there are many more product recognition awards than there are commercially successful new products. While many design awards focus on the creative or artistic aspect of the product, the key to new product commercial success is the creation of sustainable competitive advantage in the marketplace. It has been my experience that form and functional design alone are not sufficient for a pioneering product and business model. In fact, the design process must encompass the whole product experience of the stakeholders across the product consumption chain, and seek to create multiple competitive advantages to anchor the commercial success of the new product experience. As you can see from this case history, this is a strategic design process, including form, function as well as the other opportunities beyond form and function.

Case History 3 - The Bionic Wrench

3.8 Reflection on the Commercial Business Solution

Commercially successful products are rare in the when considered in the context of attempts at creating new products. Both large companies and entrepreneurial companies struggle with the ambiguity, frustration and uncertainty of seeking to create new competitively advantaged products. While there are many development models and experts claiming the expertise for new product creation, I could not find a system that was explicit in my practise. Although I did find some insights into what worked for me, and what did work in practise.

These insights did not arise from a theoretical approach or academic form of research of the process; they arose as discussed in the previous cases through the competitive practise of product design and development in the marketplace. Fortunately, early in my career, I was able to traverse the technical and business demands of the commercial marketplace, gaining insights tacitly into what stakeholder needs could contribute. Pursuing these needs through the empathic eyes of a designer, I was able to see that often-competing needs of stakeholders affected the products success. In addition, in order to raise my certainty of success I needed to design my products from a multi-stakeholder perspective.

Seeking to understand what I had tacitly acquired in practise, and apply it strategically to a new product design process, I embarked on this case history of the differentiation by design process in the creation of the Bionic Wrench and LoggerHead Tools. This journey has taken many twists and turns, and there is much more to share in the terms of the experience beyond the subject of this case history on the design process.

The Bionic Wrench has achieved commercial success in its marketplace, despite having significant competition and challenges for pioneering a new product in the highly competitive marketplace of the hand tool category. While my premise has always been that you cannot self-proclaim competitive advantage, after 10 years as an entrepreneurial start-up, LoggerHead is approaching the sales of 2.5 million Bionic Wrenches and derivative tools, we have seen many other new entrants come and go without the ability to commercially sustain their efforts.

Case History 3 - The Bionic Wrench

3.9 Reflection on Differentiation by Design as a Design Strategy

. As a case history of the process of how design can create new value and competitive advantage in commercial marketplaces, I feel that there is a very strong argument for the Differentiation by Design process, based on the results of this case history. This process arose through my tacit practise; I confirmed it through a case history in practise through the development of the Bionic Wrench. Where I began researching and seeking to explain the “how” of the design process through my creation of a Master’s level course taught at Northwestern University beginning eight years ago. Seeking to make explicit this process, I have now pursued the academic research of the Differentiation by Design process, of how design creates value and competitive advantage in commercial marketplaces. This academic research is detailed in my PhD Thesis. Below is the synthesis that evolved from my course evolution seeking to explain the process.

This item has been removed due to 3rd Party Copyright. The unabridged version of the thesis can be found in the Lanchester Library, Coventry University

Figure 3-40 Dan Brown Differentiation by Design Course Slide 2007 - 2016

Case History 3 - The Bionic Wrench

3.10 Concluding Reflection

This case is the third of three cases I have chosen of my own design work to academically research and seek to make explicit the tacit knowledge of my 30+ years of new product design and development practise. I have relied on the philosophy of Donald Schön and his theory and development of the reflective practise research process. Beginning my career as a practitioner, there were not many options for practitioners to break into the academic world or role of the traditional academy. My journey has taken me here, and I am very grateful for the opportunity. Reflecting on the insights from this experience, I can see a very viable pathway arising from practise for those practitioners seeking to build an academic career based on their tacit knowledge in practise.

Case history as a research method is an established form of methodology; it has particular applicability to product design and development because of the nature of the process as well as the data created by the projects. Data exists in this case from the engineering development, design research, testing, and validation and in the designed artefacts themselves. This case is unique due to its autobiographic nature, and the potential for researcher bias in the process. To guard against this bias the case has relied upon the historical documents that exist in the patent records, as well as the marketplace confirmation of the design's competitive advantage among the existing solutions.

Academically researching cases of design practise is not a new methodology, academics as well as researchers pursuing action research in an embedded ethnographic process have practised it. There are not many cases of auto-ethnographic research of one's own practise, but the opportunity for this methodology to contribute to new disciplinary academic knowledge has potential. This case history of an existing product that has competed successfully is a new potential academic corollary to the traditional methodology of the academic research. While it has to be acknowledged that the case and the effect of the design process on the creation of competitive advantage could have arisen from serendipity or some other modality, it is not a high probability. Further case studies of this nature are necessary to fully understand the potential for this methodology to arise as a respected contributor to the creation of new disciplinary academic knowledge.